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IMPROVING THE PERFORMANCE OF OIL SPILL CONTAINMENT BOOMS IN WAVES

Part I - Literature Review

Part II - Physical Model Study: Procedure and Results

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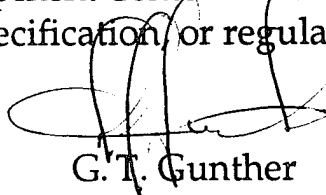
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16. Abstract This study to improve boom performance is intended to complement the ongoing oil spill research at the Ohmsett facility and within the Marine Spill Response Corporation. After an extensive review of the literature, new model testing instruments and procedures have been developed to provide a direct measure of containment boom heave response to wave excitation at several points along a catenary-towed boom. Measurements have been made in reproducible regular, irregular and breaking waves for various generic model boom configurations over a range of wave characteristics and boom buoyancy/weight ratios at typical towing speeds. Total towing forces have also been measured and are scaled up to full size predicted drags. Based on analyses of the results, highly flexible booms with buoyancy/weight ratio of at least 10 and sufficient freeboard are recommended for open sea operation with a catenary tow at about 0.5 knot.					
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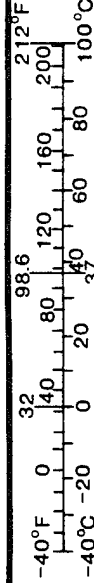
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply By	To Find	Symbol
LENGTH				
in	inches	* 2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
AREA				
in ²	square inches	6.5	square centimeters	cm ²
ft ²	square feet	0.09	square meters	m ²
yd ²	square yards	0.8	square meters	m ²
mi ²	square miles	2.6	square kilometers	km ²
	acres	0.4	hectares	ha
MASS (WEIGHT)				
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
VOLUME				
tsp	teaspoons	5	milliliters	ml
tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft ³	cubic feet	0.03	cubic meters	m ³
yd ³	cubic yards	0.76	cubic meters	m ³
TEMPERATURE (EXACT)				
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

* 1 in = 2.54 (exactly).

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply By	To Find	Symbol
LENGTH				
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
AREA				
cm ²	square centimeters	0.16	square inches	in ²
m ²	square meters	1.2	square yards	yd ²
km ²	square kilometers	0.4	square miles	mi ²
ha	hectares (10,000 m ²)	2.5	acres	
MASS (WEIGHT)				
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
VOLUME				
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	0.125	cups	c
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m ³	cubic meters	35	cubic feet	ft ³
m ³	cubic meters	1.3	cubic yards	yd ³
TEMPERATURE (EXACT)				
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



EXECUTIVE SUMMARY

A focused effort to improve boom performance in waves is underway at Stevens. This study is intended to complement the ongoing oil spill research at the OHMSETT facility and within the MSRC. After an extensive review of the literature, new model testing instruments and procedures have been developed to provide a direct measure of containment boom heave response to wave excitation at several points along the boom. Measurements have been made in reproducible regular, irregular and breaking waves for various generic model boom configurations over a range of wave characteristics and boom buoyancy-to-weight ratios at typical towing speeds or currents. A model scale of 1/8 allows for tests in regular waves up to 12 ft high full scale at 12:1 length/height ratio and irregular waves with significant heights of up to 8 ft full scale. Breaking waves can be generated at catenary boom models as they are towed down the tank. Total towing forces have also been measured and are scaled up to full size predicted drags.

The results of tests of three different size models, all scaled to the same 4 ft high prototype boom, show no scale effects on heave response to the various types of waves. A buoyancy/weight ratio of 10 or greater was found to improve heave conformance with the waves at optimum towing speeds of about 0.5 knot. Short wavelength waves, requiring the highest frequency response, are shown to be the most difficult conformance problem for oil containment booms. This is especially true because a catenary tow shape focuses waves near the vertex, thereby amplifying the wave height and the resulting motions near the center of the boom. For this reason, light weight, highly flexible booms with maximum buoyancy/weight ratio and sufficient freeboard are recommended for open sea operations. It is further recommended that model comparison tests be run at Stevens for optimization of configurational design variations in conjunction with full scale oil spill tests at the OHMSETT facility.

GLOSSARY

BARRIER/BOOM	any floating mechanical device intended to prevent the spread of floating oil, increase the thickness of floating oil, or divert the flow of floating oil.
BOOM HEIGHT	the total vertical height of the barrier at rest in calm water. The sum of draft and freeboard.
BOOM DRAFT	the maximum distance below the calm-water surface of any boom segment not part of the towing assembly or connector.
BOOM FREEBOARD	the vertical height of the barrier above the water line in calm water
BOOM SKIRT	the structural component of an oil spill boom that hangs beneath the flotation member. There is often a ballast chain or other weight at the bottom of the skirt to hold it vertically in the water.
CATENARY CONFIGURATION	the "U" or "J" plan view shape formed by a boom when towed by two vessels or held in place at two fixed mooring points.
HARBOR CHOP	an irregular condition of the water surface produced by an interference pattern of waves generated at the OHMSETT tank.
OHMSETT	"Oil and Hazardous Material Simulated Environmental Test Tank". The National Oil Spill Test Facility at NWS Earle, Waterfront Area, Leonardo, N.J.
SIGNIFICANT HEIGHT	the average of the one third highest wave height measured crest to trough; used to characterize the sea surface.
TEST TANK	a wave tank which can create a relative velocity between a boom and the water surface; a towing tank.
TOW SPEED	the relative speed difference between a boom and the water in which it is floating. Current is equivalent.
RANDOM SEA	irregular waves having a broad frequency spectrum; usually characterized by a significant height and period of maximum energy.
REGULAR WAVES	repetitive waves of the same amplitude and frequency (with a very narrow frequency band).

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INTRODUCTION TO PART I

As a result of several recent catastrophic oil spills, numerous public and private efforts have been initiated that seek to protect the marine environment from the accidental release of petroleum products. These have included the Oil Pollution Act mandating certain design and operational changes in the transport and handling of petroleum cargoes; the creation of the industry-sponsored Marine Spill Response Corporation; and the recent re-commissioning of the OHMSETT oil spill research facility. These initiatives are evidence, not only of the increased public concern about marine oil spills, but also of the inadequacies of the present state-of-the-art in our knowledge of spill behavior and cleanup/containment technology.

A continuing problem in oil spill mitigation efforts is the loss of effectiveness of spill containment booms in waves. Essentially, this problem is the result of the inability of the boom to conform to the water surface with sufficient freeboard and skirt depth to avoid the loss of oil. As a consequence, booms deployed in all but protected waterways have limited utility in stemming the spread of a surface spill. Since major accidental spills often occur in open waters exposed to heavy seas and swell, the loss of boom effectiveness severely hampers oil recovery efforts. Recent regulations requiring rapid response plans and on-board mitigation systems will, in such cases, lose much of their intended function.

Clearly there is a need for a focused effort to improve boom performance in waves. This study is intended to complement the ongoing oil spill research mentioned previously, particularly that being carried out at the OHMSETT facility and within the MSRC.

This first report is a review and discussion of previous research and design efforts at modeling and analysis of containment boom performance in waves. The currently available state-of-the-art booms will be described. Reduced effectiveness in the open sea will be studied with special emphasis on the perceived causes and potential solutions to this problem which becomes exceedingly crucial when large spills occur near a coastal environment.

PREVIOUS WORK

A search of the literature on containment boom performance, design variations and previous modeling efforts resulted in the References listed chronologically at the end of this report. Naturally many more volumes have been written on the subject in the last thirty years. The extensive references in each of the papers perused provides a more complete range of research done on the oil spill containment problem. In this report, we have tried to summarize the more directly pertinent references relating to the performance of containment booms in rough water. The listings here will be broken down into two major areas of interest: (1) ranges and types of boom designs available and (2) experimental procedures and analyses used to date.

CONTAINMENT BOOMS

This section will describe the general types and variations of boom designs available as shown in the "1993 World Catalog of Oil Spill Response Products"-Edited by Robert Schulze.²⁰ This very useful and comprehensive reference contains hundreds of booms listed according to Manufacturer/Distributor and broken down according to recommended use in (1) calm water - C, (2) protected water - P and (3) open water - O. There are 33 pages of open water boom listings alone with up to 3 design variations per page. Obviously, no single design can solve all oil containment emergencies. Boom terminology is explained in the GLOSSARY.

Open water has been defined by the new ASTM Standard F625 to correspond to the operating environment definitions listed in earlier editions of the Catalog²⁰ as "Offshore", where significant wave height is less than 6 feet (or 2 meters). Also, it is suggested in a draft ASTM Standard presented as Table 1.3 in the catalog that minimum reserve buoyancy to weight ratio of 9:1 be used for Open Water Boom selection, but that this figure will be increased in future revisions of the Standard. Overall boom heights range from 36 to 90+ inches for Open Water in this same Table.

Another textbook on the subject, "The Control of Oil Pollution"-Edited by J. Wardley-Smith in 1976,⁵ also describes boom types, uses and operational characteristics.

Three basic types of booms have proven successful in containing oil and floating oil-like materials. These types, listed in order of most used, are: (1) curtain booms, (2) fence booms and (3) external tension booms (unidirectional operation only); see Figure 1A. Each type has its place depending on the quantity and location of a spill.

Chapter 1 of the World Catalog²⁰ is recommended reading because of its excellent forty page discussion and description of containment boom design, performance and selection requirements. A brief summary of the comments directly related to open sea operations and wave limitations of available boom designs can be given here to complete the picture. Figure 2A depicts four of the principal failure modes of containment booms.

Two criteria mentioned for improving short period wave operations are: (1) flexibility with floating sections no longer than 3 to 4 feet, or continuously flexible flotation chambers and (2) a high value of reserve buoyancy to weight ratio to ensure heave stiffness in order to follow larger waves. One additional requirement for good wave following and operation in high currents is high roll stiffness, where roll is the relative angular attitude of the boom cross section. Either heavy ballast weights at the bottom of the skirt or flotation volume well outboard of the boom section centerline are used to provide large roll restoring moments to maintain a near vertical boom attitude along its length.

Naturally, adequate freeboard and skirt draft must be provided in order to operate successfully in the open sea. Surprisingly, with the normal catenary deployment in waves a 12 inch skirt draft performs as well as or better than a 24 inch skirt.¹⁴ A maximum 18 inch skirt draft limit is sometimes mentioned for operation in fast currents. Also, freeboard height should only be large enough to prevent splashover without allowing excess rolling moments to develop due to high wind forces acting on the exposed upper surface of the boom.

EXPERIMENTAL AND ANALYTICAL STUDIES

Although spill containment booms have been around a long time and earlier analytical studies exist, two papers from a Joint Conference on Prevention and Control of Oil Spills given by API and FWPCA in December

1969^{1,2} are of particular interest. The first paper by Commander Lehr of the U.S. Coast Guard and J.O. Scherer, Jr. of Hydronautics describes predictions of boom loads, shapes and motions.¹ Some model tests were undertaken to verify the analytical study using a simplified segmented model. The results are incomplete at the time of the paper. However an important design goal relating to seakeeping capability of oil spill cleanup systems is stated. That is, to "perform efficiently in 40 mph winds, 2 knot currents and 10-foot significant height waves." This recommendation by the authors also is extended to "survive, though not performing effectively, in 60 mph winds, 2 knot currents and 20 foot significant height waves." These goals are still valid for today. Larger than 10 ft significant height waves tend to mix the oil with the water and make containment and pickup very difficult.³

The second paper by Dr. Wicks of Shell Oil² presents "experimental results and their interpretation on the effects of water currents on oil containment with booms." He discusses and illustrates the important physical phenomena controlling the flow conditions that lead to failure of a barrier. His experimental work used a 60 ft long circulating water channel 6 feet tall by 6 feet wide and a plywood board to represent a section of "skirt." Showers of oil droplets were observed to be torn off from a head wave formed at the bottom of the oil above about 0.6 fps. If the slick was long enough the oil torn off could be recovered before passing under the skirt. Otherwise, containment is lost. Dr. Wicks computes the trajectories for oil of different specific gravities and surface tension values.

Milgram and O'Dea in 1974 evaluate the strength and seakeeping ability of arbitrary barriers using both model tests in a swimming pool and theoretical and semi-empirical analyses. The effects and various methods of carrying the tension throughout the barrier are studied. Model scaling is discussed and it is concluded that fabric thickness, strength and bending stiffness cannot be scaled for a small scale model due to difficulty in obtaining such weak fabric. It is stated that the folding tendency of the fabric cannot be determined from model tests but that all other aspects of barrier motion can be determined.⁴ "Model tests can be used to estimate the heave, sway and roll motions of a barrier."

Milgram in a 1977 paper⁶ shows photographs of the build up of the head wave on the bottom of oil on water at a barrier and failure due to separation above a one knot current. A later paper⁷ shows an interesting combination barrier and weir-type skimmer oil recovery system that was first tested in the OHMSETT facility in 1975 and then demonstrated in sea trials with the U.S. Coast Guard in May 1976. Weir skimmers are inherently simple but good oil collection requires that the attached boom follow the vertical motion of the waves. The Coast Guard barrier design was used and performed well in seas up to 5 ft significant height.

McCracken⁸ describes the OHMSETT standardized test procedures and results for eight boom systems. Booms were first tested for stability capabilities over a wide range of wave conditions without oil and then in wave conditions within their operational stability limits with two types of oil. In another paper⁹ recovery efficiency was measured for simulated hazardous floating materials and compared with previous oil recovery tests. No differences were shown.

Milgram and Van Houten^{10,11} describe the mechanics of a restrained layer of floating oil analytically and using the flume at MIT. The second paper studies the oil-water interface stability with respect to movement of the oil slick by the water waves.

Corpuz and Griffiths¹² performed open sea field tests for the Coast Guard of six offshore oil containment booms in 1977 in the Gulf of Mexico but without oil. One of the major U.S. made products performed well in significant wave heights of 8 to 10 feet and survived in waves up to 14 feet. Signs of possible containment failure due to splashover were observed only occasionally. Results indicated that "both ballast and reserve buoyancy of offshore booms should be as high as practical."

Environment Canada in 1980¹³ tested six offshore booms in severe seas with small amounts of oil. The results indicated some oil could be recovered if the pick up had been attempted within 45 minutes for the best performing product.

Smith and Lichte¹⁴ present a summary of the U.S. EPA's OHMSETT testing from 1974 to 1979. Descriptions of the facility, its capabilities and wave

making system are given. Test procedures depend on product being tested.

A National Marine Pollution Program Plan for research, development and monitoring for 1981-1985¹⁵ stated that federal program emphasis has shifted to the containment and pick-up of floating hazardous materials requiring more study of the necessary technology.

Environment Canada's winter evaluation of skimmers and booms¹⁶ describes good agreement with theoretical curves of boom towing force as a function of gap ratio at smaller gap ratios but at larger gap ratios the measured forces are lower. In the offshore tests of the Vikoma Seapack it was noted that the upper and lower cylinders of the boom set up local currents as the boom moved up and down in waves. This kept oil away from the boom surfaces.

Borst and Lichte¹⁷ in 1983 and 1984 performed two series of tests on five booms. One series was in the OHMSETT facility and the second series of open-water tests was in the Raritan Bay. A standardized test matrix was used for oil-holding ability. Wave conformance and endurance were observed in the tank under controlled conditions. Wave conformance of 500-ft booms deployed in the bay was then compared with the 100-ft lengths used in the tank, but lack of conformance was more obvious in the bay tests. Additional tests were planned in an effort to obtain better correlation, but the results are unpublished.

Meikle¹⁸ in 1987 explains Environment Canada's more recent work in marine-spill countermeasures. He mentions the Vikoma booms in inventory as being at least as good as some of the newer booms tested.

Finally, a Test Protocol for the Evaluation of Oil-Spill Containment Booms¹⁹ has been updated to the present and serves as a guide for current OHMSETT and offshore testing. This reference, together with the contents of the 1993 World Catalog,²⁰ will be used for selecting generalized boom shapes and proportions relative to the test tank at Stevens for the next phase of this study.

GENERAL RECOMMENDATIONS

Based on previous experience and analyses the following recommendations

are made concerning oil boom design and selection for extending open sea operations from waves of 6 ft significant height to as much as 10 ft:

(1) good flexibility with floating sections no longer than 3 to 4 feet, or continuously flexible flotation with a smooth surface.

(2) reserve buoyancy/weight greater than or equal 9:1.

(3) high roll stiffness with either heavy ballast weights at the bottom of the skirt or flotation volume arranged to provide large roll restoring moments.

(4) total height large enough to provide freeboard above maximum wave splashover and skirt or fence draft sufficient to contain the oil and prevent drainage failure at the expected towing or drift speeds.

(5) sufficient strength to survive extreme seas and to take the towing forces in winds of 40 mph at 2 knots towing speed in 10 ft significant height waves.

There are booms built today that can possibly accomplish the desired objective of containment in 10 ft waves. However, open sea tests are few and difficult and accurate measurements, even of the sea conditions, are usually limited.

A test plan will be developed for a model examination of boom response to large waves using the Stevens tank. This will require a basic scale ratio of $1/4$. Boom gap will be restricted to about 8 ft for the model, thereby allowing a 12 ft model boom length to fit the prescribed test gap ratio of $2/3$ and a 24 ft boom length to fit a gap ratio of $1/3$. A model boom draft of one foot or less will be required due to the tank depth of 5 feet for large waves. Waves up to 18 inches high can be made with this depth, representing 6 feet for a $1/4$ -scale and 12 feet for a $1/8$ -scale model, also to be included in the study.

INTRODUCTION TO PART II

This is the second part of a study concerned with improving the performance of oil spill containment booms in waves. Uniform tank testing procedures are developed for assessing boom performance in waves based on a previous review and adopted good practice. Guidelines are provided for test setup and a wave/current test matrix is developed that allows for the subsequent boom analyses and comparisons. In addition, data analysis procedures are explored for predicting each boom's response to full scale random sea waves.

A series of generic model booms was developed, constructed and tested. A brief analysis was made to compare the effects of variations in scale, buoyancy/weight ratio, speed, wave height and gap/length ratio on heave response to waves and total towing force. All final tests were performed in the No. 3 towing tank at the Davidson Laboratory of Stevens Institute of Technology during April 1994. Many of the tests were witnessed by Lt Michael J. Roer of the U.S. Coast Guard as well as other interested parties.

The objective of this study is to produce a document of model testing procedures and analysis techniques that will assist future efforts in containment boom research and development for extending open sea operations.

MODELS

In accord with the findings of Part I of this study the most flexible, smooth-sided longitudinal shape possible was selected as the basic boom model to be tested in the catenary tow condition; see Figures 1-8. Two primary variables that had to be examined were model size (to best fit the tank cross section) and non-dimensional buoyancy/weight ratio. Table 1 lists the dimensions, materials and resulting B/W ratios available as a result. The latest ASTM recommended B/W value of 10 was included for all models. In addition, boom gap/length ratio could be varied by length changes with the 8 ft gap width dictated by tank width. Wave size limits available in the towing tank then determined the boom scale factors to be considered, since boom height for open sea operations is indeterminate at present. However, it would appear to be at least 4 ft based on current

practice.¹⁶ Some have recommended a boom height at least equal to operational wave height for a barrier that contains the boom tension members internally.¹³ The resulting air-inflated curtain boom cross section was developed and three size variations were constructed by Slickbar Products Corporation to dimensions specified by the Davidson Laboratory. Three scales were decided upon for a 4 ft high full scale boom -- 1/8, 1/4 and 3/8 -- with a basic length of 24 ft with additional changes in this length possible for future testing of gap/length ratio. These extremely light weight boom models permitted the inclusion of more variation in B/W ratio than had originally been planned. The variations in B/W were obtained by adding lead weights to the two larger booms in increments of 0.465 lb and by different sash chains threaded through the bottom fold of the smallest 6 inch height boom; see Table 1 and Figures 3, 4 and 5. A special bleed fitting was made and used to measure and set the very low air pressure of 0.5 inches of water over atmospheric in the buoyancy chambers. An available Pennwalt Corp. Electro-Pneumatic Calibrator Series 65-125, by Wallace and Tiernan Div. shown in the middle of Figure 7 was used to read the pressure which remained very constant in the tow tank.

TEST CONDITIONS

Previous research with catenary towed booms and oil has shown an optimum tow speed of from 0.5 to 0.7 knot with a critical speed of about 1.0 knot above which oil starts to pass under the boom at a rapid rate. For this reason a model test speed range equivalent to currents or relative tow speeds of from 0 to 3 knots full scale was selected. Preliminary trial runs in calm water soon eliminated the 3 knot equivalent test speed and resulted in an upper practical tow speed limit of 2 knots. Table 2 lists the final ranges of all variables tested. The upper limits of the computer controlled wavemaker allow up to 18 inch or 1.5 ft regular waves at a minimum length/height ratio of 12:1 to prevent breaking. Thus, 0.5, 1.0 and 1.5 ft regular 12:1 waves were included.

A maximum irregular ITTC wave with a Pierson-Moskowitz spectral distribution of heights can be generated with up to 1.0 ft significant height waves and the corresponding period of maximum energy of 2.768

seconds. Similarly, a 0.5 ft significant height of 1.957 sec maximum energy period and a 0.75 ft significant height irregular wave of 2.397 sec period were included in the wave/current test matrix. Note that early problems with the computer controlling the wavemaker cut short and even prevented some runs in the 1.0 ft significant height waves for the 1.0 ft height boom. This was later rectified and this largest irregular wave was included for all other models tested. A third type of wave available for these tests was included in order to complete the picture for the video observations. Namely, breaking waves to show the behavior of containment booms under the severest wave (and weather) conditions.

Appendix A shows the measured model wave spectra for the three irregular wave sizes tested as well as an oscillograph time history of the breaking wave developed from deep-water breaking wave theory. This breaking wave is made through a sequence of seven waves which produce one breaking wave of large magnitude in a repeatable manner down the length of the towing tank.

APPARATUS AND PROCEDURE

Figures 1 and 2 show sketches of the model and support apparatus towing arrangement. Figure 6 shows photographic close-ups of the 150 lb stainless steel drag balance, cross-tank beam of adjustable span and height with tow struts system (one strut shown), one heave transducer and, finally, the four 4 ft tall wave struts mounted at fore and aft locations corresponding to the heave transducer locations along the boom. Figure 1 shows how the aft 3 wave struts were relocated for each different boom length corresponding to the wave phasing at each heave unit location. Special rigid support tracks were constructed and mounted parallel to the model centerline 2, 3 and 4 ft outboard and approximately 3 ft above mean water level. The four specially designed heave transducers were built in house after early trial runs revealed the need for them. Their specifications as finally constructed include: 16 gram low inertia pulleys, 60 + inches of heave travel with constant 0.1 lb lift force and ± 0.01 lb total friction (even with misalignments of up to 6 inches at the water surface) using a linear output Bourns Series 3540 10-turn pot. Special new bridge circuits were built for the four wave wires to provide extremely good linearity and response to wave

elevation with better stability independent of small electrical currents in the tank.

Swivel-mounted tow yokes were attached to each boom end and were clipped to heavy duty fishing swivels at the bottom of each towing strut at the mean water level. A five foot yoke length was used for 24 ft boom length tests while a four foot yoke length was required for the 12 ft boom length in order to keep the tow strut spacing within the tank width for the 8 ft gap at the forward ends of the boom catenary; see Figure 1. A light weight Nylon return string was attached to each boom at the vertex. This string was long enough to remain slack throughout the largest heave excursions and only become taut when returning the model to the wave beach end of the tank to prepare for a new run. This string also protected the low force heave transducers from running all the way out to their stops during reverse runs.

Each test run was made by starting the waves, then starting the tow carriage (except for zero speed runs) when the waves reached the beach and filled the tank. Video recorders, and oscillograph recorders were started just prior to each run. The computer was made ready to read data on all channels once the model was up to steady speed where a pulse signals it to start and stop taking data. The video records show each model from the beginning to the end of a run.

The length of the bottom tension cable of each new boom had to be adjusted or "tuned" to provide the optimum towing attitude in calm water trials prior to running in waves. Mr. Edward Tedeschi of Slickbar Products Corporation, an experienced boom engineer, guided the test crew in this important procedure.

DATA PROCESSING

Each channel of instrumentation was linear and was calibrated prior to testing. Reference zeros were taken before each group of runs. Oscillograph records were taken for all runs in order to monitor the behavior of each channel transmitted to the Masscomp computer. Data were sampled 20 times a second and were processed on the in-house computer for mean values, rms (root-mean-square) values and maxima (peaks) and minima (troughs) where applicable during rough water testing throughout the 70 ft

data trap with the model at constant speed. At zero speed, data was taken for 128 seconds with the model oscillating in the wave train. During irregular and breaking wave tests a peak-trough analysis was carried out on all heave and wave channels to compute the mean, rms, the number of oscillations, the average of the peaks and troughs, the average of the 1/3-highest and the 1/10-highest peaks and troughs and the extreme values of each. These were output in the results Table 6 in a two-line format: mean/rms, oscillation/buffer and peak/trough. In this statistical analysis spurious oscillations are suppressed by means of "buffers", which are minimum amplitude limits set to eliminate electrical or vibrational noise on a data channel. Thus, oscillations smaller than the buffer riding on the back of larger waves in the individual time histories are neglected.

PRECISION

The precision of the measurements made during these tests is estimated to be within the following ranges model scale:

<u>Measurement</u>	<u>Precision</u>	<u>Range</u>
heave	± 0.30 in	60 in
wave (elevation)	± 0.10 in	40 in
drag	± 0.30 lb	200 lb
speed	± 0.01 fps	100 fps
period	± 0.002 sec	
regular waves		
period of max. energy	± 0.01 sec	
irregular waves		
period	± 0.05 sec	
breaking waves		

RESULTS

The results of these tests are presented in several tables in various formats. Table 3 is a complete log of the video runs and is to be used when viewing any of the 4 tapes that include about 6 hours and 45 minutes of low speed running. Tables 4, 5 and 6 give all the data model scale. Tables 7,

8 and the data comparisons in Table 9 are given for a full scale 4 ft high boom using Froude scaling laws and the scale ratios selected for the three different height models. Full scale drags include a correction for the density of sea water at 59 deg F as compared with fresh water at 70 deg F in the towing tank. Table 9 presents the influence of variations in scale, B/W, wave height, gap/length ratio and tow speed on vertex heave response and drag.

Figures 9 through 17 show direct comparisons of superimposed heave and wave time histories of the model responses at the four locations along each boom in 0.75 ft significant height irregular waves for twenty second samples of the runs.

Figures 18 through 20 present model response amplitude operators (RAO) computed from the digitized time history measurements in 0.5 ft significant height irregular waves at the three different buoyancy/weight ratios covered for the 1 ft x 24 ft model boom. Figures 21 through 23 show the same three irregular wave RAO examples but with superimposed RMS heave response ratios measured in regular waves at specific frequencies of encounter.

Figure 24 shows predicted full scale drag as a function of speed for the several model scales and for three values of B/W for the intermediate (1/4) scale model.

The heave data and responses for the 1 x 12 ft model boom at locations 2 and 3 were eliminated from the results tables because of serious misalignments made in mounting the connections to this short length boom model. Since this did not affect the response of the boom at the most important locations 0 and 4, the tests were not repeated.

ANALYSIS AND DISCUSSION

A first analysis begins with the model scale results presented in Tables 4, 5 and 6 with test speeds listed by run number in Table 5 as well as encounter frequency ($2\pi/T_e$) for all regular wave runs. Table 5 RMS heave response ratios are presented for all runs but are particularly meaningful for regular wave runs with specific wave encounter frequencies. It was first believed that the magnitudes of these response ratios would be a key measure of boom conformance to a wave system. However, other factors enter in. For example, in short length waves a focusing or amplifying effect

develops due to waves either reflecting and/or being refracted off the inner boom surfaces. As a result, in short period and length waves - namely the 0.5 ft high by 6 ft long waves - the waves encountered at the centerline or vertex of the catenary tow shape are visibly greater in height than the waves measured outside of the boom nearer the wall; see Figure 1. In addition, the waves inside the boom can become irregular in a non-periodic manner. Thus, a flexible curtain boom cross sectional shape appears to reflect or focus short period waves at some tow speeds resulting in a heave response factor of much more than 1.0, up to 1.4, relative to the wave height measured at an outer location at the same longitudinal position along the boom. Since the primary area of interest is near the vertex when collecting oil, this makes analysis using this rms/rms factor or response amplitude much more difficult to interpret. These larger response amplitudes occur at the centerline (0) heave location for all boom combinations tested, indicating some reflection or focusing of all wave sizes and lengths. The other locations 2, 3 and 4 ft outboard of the centerline show responses much closer to 1.0, or less when poorer conformance is exhibited; see Table 5. More discussion of this will follow.

The second stage of analysis is to look more deeply into the irregular wave results whose statistics were measured and listed in Table 6. Time histories were plotted for 20 second samples of the runs for three boom sizes at three B/W ratios in 0.75 ft significant height waves for the model test speed corresponding to 0.5 knot full scale; see Figures 9 through 17. These directly superimposed comparisons of heave and wave measurements at the same locations 0, 2, 3 and 4 ft outboard of the centerline show how well these flexible curtain booms really do conform to the waves at appropriate tow speeds. The phasing correlation is very good in this rather large wave system and was observed to be similar in all size irregular waves.

The next step was to compute response amplitude operators for selected runs, see Figures 18 through 20, for three B/W ratios. These three figures show some differences in response to a given size irregular wave over the wide variation in B/W ratio. Further analysis was completed by plotting the regular wave response amplitudes at the specific values of frequency of encounter taken from Table 5 on these same irregular wave RAO plots, now called Figures 21 through 24, for locations 0, 2, 3 and 4 ft out. Study of Figures 21 - 24 shows remarkably similar trends in heave response variation

with encounter frequency over the band of regular wave frequencies tested. This finding is important because it shows that the results of regular wave testing over a range of frequencies are roughly equivalent to irregular sea heave response behavior. Regular wave test procedure is followed at OHMSETT for boom tests with oil in all but "harbor chop" waves.

Note that while RAO is non-dimensional in Figures 18-23 and would not change with scale factor, $2\pi/Te$ is dimensional and would vary with scale factor. In fact, the frequency values would be reduced by a factor of $1/\sqrt{\text{scale}}$. Thus, $(2\pi/Te)_{FS} = (2\pi/Te)_{MS} \times 1/\sqrt{\text{scale}}$, or wave encounters occur at a slower rate for a full scale boom. Maximum heave response is seen to occur at about 6 radians/sec for the 1/4 scale 1 x 24 ft boom model centerline location. This would become 3 radians/sec for an equivalent full size 4 ft high boom at 0.5 knot for all three B/W ratios. For future work, repeat runs at any given irregular wave height/speed condition would improve the correlation coefficient over a wider range of encounter frequencies for the RAO computer fit of resulting data. This would allow greater confidence in providing the variations in heave response for a given condition, since different height irregular waves would be expected to shift the encounter frequency and magnitude of heave response because of the basic non-linearity of the boom/wave system.

Figure 24 presents full scale drag variation as a function of speed for the wide range of boom lengths and B/W tested. As would be expected, lower B/W requires higher towing forces. These forces also vary with boom length and wave height to varying degrees as has been described before.²⁰

Table 9 has been prepared in order to compare the effects of the most important parametric variations on centerline heave response and required towing force. For these comparisons all speeds and drag forces have been expanded to full scale values using the listed model scale ratios, resulting in a 4 ft boom height for each size model with the given dimensions. The first comparison shows a mean value of centerline heave response of $1.4 \pm .13$ for all three model scale ratios for both 0.5 and 1.0 knot tow speeds in 12:1 regular waves at B/W = 10. The second comparison shows similar heave response values for B/W = 34 and 10 but a higher value for B/W = 4.4 of about $1.74 \pm .09$ for the 1/4 scale model results at both speeds. The third comparison of wave height effects on heave response shows slowly declining

response values as wave height increases - from 1.4 to 1.3 to 1.2 as wave height is increased from 4 to 8 to 12 ft at $B/W = 10$ and 0.5 and 1.0 knot tow speeds. Finally, the fourth comparison made is for the effect of gap/length ratio where doubling the ratio produces no statistically significant difference in centerline heave response to 4 ft high waves at 0.5 and 1.0 knot tow speeds.

Many other comparisons may be made using this data but these are the important variables and parameters. It was fortunate that the wave/speed test matrix focused on the shortest wave length regular waves because these 12:1 length/height waves with an approximately 1 second period model scale provided the most interesting behavior and measurements for these boom models. Video observations of all runs in these short length regular waves show the irregularities of wave motions and resulting heave motions developed particularly at the vertex location 0 of each boom. Study of the videos here shows that water splashes up at the vertex, where oil would be collecting and splashes back and over the boom occasionally as tow speed reaches 1.0 knot or higher equivalent full scale speeds. This same behavior is observed in all the short wave length regular wave runs.

As expected and demonstrated here, breaking waves will top any boom whose freeboard is less than the breaking height of the wave.

CONCLUSIONS

Scale model oil containment booms have been successfully designed, constructed and tested in waves at three different scale ratios. The measured heave responses to equivalent wave sizes show excellent agreement at useful towing speeds equivalent to 0.5 and 1.0 knot full scale for all three model scales at the boom vertex during catenary towing. Total required towing forces are different due to the different full scale lengths of boom dictated by the test tank width and, therefore, model gap available.

Three different buoyancy/weight (B/W) ratios were tested for each boom scale by varying skirt weights on these curtain boom shapes. The effects as shown and discussed reveal relatively small differences between B/W of 34 and 10 but somewhat poorer heave conformance with waves at $B/W = 5$. Towing drag forces naturally increase with lower B/W , since the booms sit deeper in the water as B/W is reduced.

Wave height is not the limiting factor for good boom conformance but rather wave steepness seems to be the dominant parameter, particularly at short wave lengths, where it becomes more difficult for the boom to respond fast enough to the rapid vertical motions of the waves. This explains why lower values of B/W exhibit poorer response than higher values because of the increased inertia that must be overcome. Apparently, $B/W = 10$ and above meets this critical need better than lower values.

Drag and boom tension forces increase rapidly with towing speed and (at a lower rate) for increasing boom length for the same gap/length ratio. Increasing gap/length ratio from $1/3$ to $2/3$ for the same full scale gap has relatively insignificant effect on vertex heave response but does increase drag forces at the same B/W and speeds of 0.5 to 1.0 knot.

RECOMMENDATIONS

The newly-designed apparatus, procedures and wave/speed test matrix developed for these tests demonstrates a method for obtaining and analyzing behavior of oil containment booms in all types of large wave systems. Comparisons between many different designs are now possible for optimization at reasonable cost prior to the need for actual full scale tests with oil. The calming effects of oil on water are not reproduced here in the small test tank but should be investigated at the larger OHMSETT facility designed specifically for testing oil spills. There, the optimum boom designs may then be studied more closely for oil control.

It is recommended for future tests that the middle size model boom height of one foot be used since it is the smallest at which a full range of B/W ratios are available due to strength and weight limits of available fabrics.

The computed curves of heave RAO as a function of frequency can be improved upon in future tests by making repeat runs at speed in various irregular wave events in order to increase correlation or predictability over a desired range of frequencies.

As demonstrated here, optimum towing speed is about 0.5 knot, or certainly less than 1 knot, where splash up at the vertex begins to be carried back over the boom. Buoyancy/weight ratio should be at least 10 or greater for best conformance with short wavelengths. Higher B/W values also

allow lower catenary towing forces.

Model data from these tests can be expanded to other larger scale booms and waves as long as the drag and speeds are scaled up also. For example, doubling the current model scales to 1/16, 1/8 and 3/16 (instead of 1/8, 1/4 and 3/8) would result in forces approximately 8 times those reported here but at corresponding full scale speeds of 0, 0.7, 1.4 and 2.8 knots for an 8 ft high full scale boom. The wave sizes would be doubled as well.

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TABLE 1

MODEL CONFIGURATIONS

Test Order	Boom Dimensions			Materials			B Buoyancy	W Weight	B/W	Figures
	Height ft	Length ft	Diameter in	Fabric	Density oz/sq yd	Color				
4	0.5	24	2	Urethane	6.5	yellow	1b	1.97	16.2	1,3
6				coated				2.56	12.5	
5				Nylon				3.35	9.6	
1	1.0	24	4	"	6.5	yellow	125	3.64	34.3	1,2,4
2								12.01	10.4	
3								28.75	4.4	
10	1.0	12	4	"	6.5	yellow	62.5	6.30	9.9	1,4
7	1.5	24	6	"	11.3	black	275	8.19	33.6	1,5
8								26.79	10.3	
9								54.69	5.0	

TABLE 2
MODEL TEST CONDITIONS

Test Order	Boom Height ft	Boom Configuration Length ft	Gap Length	B/W	Wave Configuration Type	Height ft	Length ft	Period Max Energy sec	Nominal Scale	Full Scale Speed knots
4	0.5	24	1/3	16.2	Regular	0.5	6	1.083	1/8	0,0.5,1,2
						1.0	12	1.539		0.5,1
						1.5	18	1.932		0.5,1
					Irregular	0.5	---	1.957		0.5,1
						0.75	---	2.397		0.5,1
						1.0	---	2.768		0.5
					Breaking	1.4	---	1.5		0.5,1
6	0.5	24	1/3	12.5	Repeat	Repeat			1/8	Repeat
5	0.5	24	1/3	9.6	Repeat	Repeat			1/8	Repeat
1	1.0	24	1/3	34.3	Repeat*	Repeat*			1/4	Repeat*
2	1.0	24	1/3	10.4	Repeat**	Repeat**			1/4	Repeat**
3	1.0	24	1/3	4.4	Repeat**	Repeat**			1/4	Repeat**
10	1.0	12	2/3	9.9	Repeat	Repeat			1/4	Repeat
7	1.5	24	1/3	33.6	Repeat	Repeat			3/8	Repeat
8	1.5	24	1/3	10.3	Repeat	Repeat			3/8	Repeat
9	1.5	24	1/3	5.0	Repeat	Repeat			3/8	Repeat

* 1 ft significant height irregular wave data limited

** No 1 ft significant height irregular wave data

Note - 3 knot (full scale) tow speed eliminated after trial runs

TABLE 3.1

VIDEO LOG

INDEX	RUNS	MODEL BOOM		WAVES			COMMENTS
		Height	Length	Type	Sig Ht	Period	
hr:min:sec		ft	ft		ft	Max Energy sec	
TAPE 1							
0:19	1-4	1	24	Regular	0.5	1.083	Short run, then wave machine failure
9:03	5-7		34.3	Regular	1.0	1.539	
16:18	8,9			Regular	1.5	1.932	
22:12	10,11			Irregular	0.5	1.957	
17:54	12			Irregular	1.0	2.768	
29:53	13,14			Irregular	0.75	2.397	Runs 23 & 24, string short
35:13	15,16			Breaking	1.4	1.5	
39:53	17-20	1	24	Regular	0.5	1.083	
47:50	21,22		10.4	Regular	1.0	1.539	
53:16	23-26			Regular	1.5	1.932	
1:03:33	27,28			Irregular	0.5	1.957	Port air pressure low at end of Run 46 Air pressure set 0.6 inch of water
1:08:35	29,30			Irregular	0.75	2.397	
1:13:49	31,32			Breaking	1.4	1.5	
1:17:37	33-36	1	24	Regular	0.5	1.083	
1:26:31	37,38		4.4	Regular	1.0	1.539	
1:31:51	39,40			Regular	1.5	1.932	Says 6 in x 1.96 sec wave
1:36:48	41,42			Irregular	0.5	1.957	
1:43:20	43,44			Irregular	0.75	2.397	
1:47:13	45,46			Breaking	1.4	1.5	
1:52:46	47-49	0.5	24	Calm	----	-----	
TAPE 2							
0:32	50-53			Regular	0.5	1.083	
10:55	54,55			Regular	1.0	1.539	
17:58	56,57			Regular	1.5	1.932	
25:07	58,59			Irregular	0.5	1.957	
32:52	60			Irregular	1.0	2.768	
37:33	61,64			Irregular	0.75	2.397	
44:32	63,64			Breaking	1.4	1.5	

TABLE 3.2

VIDEO LOG

INDEX	RUNS	MODEL BOOM		WAVES		COMMENTS	
		Height	Length	Type	Sig Ht	Period	Max Energy
hr:min:sec		ft	ft		ft	sec	
TAPE 2 Continued							
51:57	65-68	0.5	24	Regular	0.5	1.083	Air pressure set 2.9 inches, Run 67 cut short
1:00:34	69,70			Regular	1.0	1.539	
1:07:33	71,72			Regular	1.5	1.932	
1:14:24	73,74			Irregular	0.5	1.957	
1:21:27	75,76			Irregular	0.75	2.397	
1:28:37	77			Irregular	1.0	2.768	
1:33:30	78,79			Breaking	1.4	1.5	
1:40:20	80-83	0.5	24	Regular	0.5	1.083	
1:50:11	84,85			Regular	1.0	1.539	
TAPE 3							
0:27	86,87			Regular	1.5	1.932	
7:36	88,89			Irregular	0.5	1.957	
14:39	90,91			Irregular	0.75	2.397	
21:59	92			Irregular	1.0	2.768	
26:39	93,94			Breaking	1.4	1.5	Run 93 end cut short
33:22	95-98	1.5	24	Calm	----	-----	Run 98 says 97
37:37	99-102			Regular	0.5	1.083	
44:26	103-105			Regular	1.0	1.539	
49:03	106,107			Regular	1.5	1.932	
53:02	108,109			Irregular	0.5	1.957	
57:02	110,111			Irregular	0.75	2.397	
1:01:21	112			Irregular	1.0	2.768	
1:04:14	113-115			Breaking	1.4	1.5	Run 114 repeat for waves

TABLE 3.3

VIDEO LOG

INDEX	RUNS	MODEL BOOM		WAVES		COMMENTS	
		Height	Length	Type	Sig Ht	Period	Max Energy
hr:min:sec		ft	ft		ft	sec	
TAPE 4							
0:00	116-119	1.5	24	Regular	0.5	1.083	
6:15	120,121			Regular	1.0	1.539	
10:30	122,123		10.3	Regular	1.5	1.932	
14:36	124,125			Irregular	0.5	1.957	
18:49	126,127			Irregular	0.75	2.397	
23:08	128			Irregular	1.0	2.768	
25:55	129,130			Breaking	1.4	1.5	
30:04	131-134	1.5	24	Regular	0.5	1.083	
35:59	135,136			Regular	1.0	1.539	
40:11	137-139		5.0	Regular	1.5	1.932	Heave 3 broke, Run 138
45:52	140,141			Irregular	0.5	1.957	
50:03	142,143			Irregular	0.75	2.397	
54:20	144			Irregular	1.0	2.768	
56:57	145,146			Breaking	1.4	1.5	
1:00:59	147-149	1	12	Calm			
1:07:42	150-152		9.9	Regular	0.5	1.083	
1:13:44	153,154			Regular	1.0	1.539	
1:18:38	155,156			Regular	1.5	1.932	Heave 0 broke late 156;OK
1:23:49	157,158			Irregular	0.5	1.957	
1:28:50	159,160			Irregular	0.75	2.397	
1:34:07	161			Irregular	1.0	2.768	
1:37:34	162,163			Breaking	1.4	1.5	
1:42:45	164			Regular	0.5	1.083	0 speed data

TABLE 4.1
MODEL ROOT-MEAN-SQUARE MEASUREMENTS
Heave and Wave Height at Corresponding Locations

RUN	Heave0 in	Heave2 in	Heave3 in	Heave4 in	Wave0 in	Wave2 in	Wave3 in	Wave4 in
1	2.605	1.649	0.919	2.041	1.762	1.789	1.840	1.806
2	2.212	1.570	1.071	1.738	1.553	1.537	1.526	1.614
3	2.646	1.426	0.979	1.665	1.666	1.687	1.709	1.748
4	2.167	1.181	0.668	0.716	1.609	1.629	1.683	1.799
5	5.579	4.369	3.513	4.521	3.883	3.998	3.949	3.975
6	5.284	4.240	3.667	4.556	3.839	3.985	4.038	4.129
7	5.481	4.315	3.368	4.568	3.934	4.074	3.975	4.025
8	7.720	6.734	5.864	6.460	6.091	6.201	6.358	6.400
9	7.699	6.778	5.650	6.459	5.882	5.930	6.136	6.096
10	1.763	1.420	1.247	1.537	1.326	1.338	1.360	1.375
11	1.912	1.474	1.403	1.496	1.357	1.395	1.404	1.465
12	4.302	3.516	2.972	3.069	3.190	3.143	3.167	3.059
13	2.706	3.244	2.825	2.268	2.140	2.146	2.223	2.194
14	3.072	2.421	2.180	2.227	2.192	2.229	2.238	2.311
15	3.420	2.424	2.118	2.387	1.877	1.939	2.180	2.166
16	3.068	2.512	2.323	2.591	2.140	2.174	2.214	2.251
17	2.362	1.812	1.613	2.334	1.638	1.744	1.765	1.847
18	2.100	1.526	1.110	1.709	1.480	1.502	1.574	1.684
19	3.015	1.650	0.773	0.719	1.782	1.813	1.904	1.882
20	1.932	1.115	0.735	0.499	1.675	1.744	1.792	1.855
21	5.276	4.054	3.699	4.311	3.735	3.985	4.161	4.126
22	5.667	4.322	3.351	4.345	3.867	4.030	3.994	4.046
23	7.287	6.486	6.107	5.754	6.148	6.118	6.243	6.465
24	7.693	6.699	5.961	5.733	5.748	5.762	6.025	6.235
25	7.816	6.702	5.913	5.684	5.750	5.772	5.980	6.227
26	7.392	6.411	5.955	5.692	6.138	6.087	6.245	6.325
27	1.869	1.482	1.333	1.555	1.341	1.380	1.374	1.400
28	2.041	1.437	1.301	1.241	1.316	1.375	1.411	1.415
29	2.948	2.552	2.157	2.160	2.098	2.121	2.235	2.212
30	3.241	2.419	2.065	1.801	2.275	2.267	2.234	2.332
31	3.547	2.766	2.519	2.695	2.545	2.567	2.655	2.688
32	3.823	2.686	2.163	2.092	2.048	2.113	2.447	2.361
33	2.880	1.766	1.377	2.431	1.616	1.733	1.816	1.909
34	2.177	1.516	1.128	1.698	1.476	1.509	1.498	1.552
35	2.926	1.529	0.847	1.011	1.650	1.698	1.820	1.836
36	1.488	0.798	0.987	0.305	1.646	1.706	1.760	1.854
37	6.267	4.190	3.813	4.136	3.434	3.913	4.131	4.139
38	5.968	4.230	3.410	4.140	3.622	3.914	3.846	3.874
39	7.537	6.434	6.033	5.814	6.048	6.056	6.176	6.475
40	8.945	6.609	5.900	5.553	5.770	5.812	5.991	6.326
41	2.041	1.522	1.358	1.558	1.362	1.402	1.420	1.467
42	2.030	1.510	1.274	1.229	1.302	1.371	1.442	1.463
43	3.430	2.321	2.186	2.289	2.114	2.120	2.222	2.232
44	3.698	2.515	2.128	1.934	2.210	2.221	2.256	2.334
45	4.350	2.848	2.606	2.843	2.601	2.611	2.735	2.763
46	4.514	2.867	2.218	2.148	1.970	2.081	2.486	2.355

TABLE 4.2

MODEL ROOT-MEAN-SQUARE MEASUREMENTS
Heave and Wave Height at Corresponding Locations

RUN	Heave0 in	Heave2 in	Heave3 in	Heave4 in	Wave0 in	Wave2 in	Wave3 in	Wave4 in
50	3.071	1.528	1.414	2.175	1.920	1.842	1.957	1.992
51	2.304	1.512	1.392	1.909	1.634	1.650	1.605	1.594
52	3.201	1.657	1.410	1.760	1.636	1.676	1.655	1.677
53	5.341	2.037	1.420	1.534	1.705	1.690	1.697	1.739
54	5.219	4.567	3.547	3.607	3.935	4.201	4.284	4.125
55	5.250	4.263	3.241	3.720	4.067	4.113	3.990	4.119
56	7.412	7.618	6.565	5.513	6.180	6.151	6.339	6.234
57	8.112	6.709	6.271	5.827	6.045	6.177	6.284	6.292
58	1.762	1.465	1.416	1.610	1.486	1.484	1.474	1.499
59	2.068	1.500	1.388	1.499	1.501	1.519	1.496	1.489
60	3.647	3.382	3.192	2.867	3.216	3.232	3.264	3.132
61	2.777	2.374	2.253	2.263	2.302	2.270	2.306	2.317
62	3.246	2.441	2.301	2.072	2.214	2.249	2.324	2.294
63	3.860	3.019	2.798	2.892	2.744	2.740	2.803	2.830
64	4.434	3.052	2.746	2.607	2.584	2.598	2.668	2.662
65	3.100	1.593	1.542	2.535	1.869	1.909	1.960	1.957
66	2.172	1.467	1.282	1.976	1.498	1.553	1.496	1.524
67	2.588	1.519	1.155	1.702	1.788	1.791	1.713	1.717
68	3.762	1.616	0.904	1.246	1.888	1.886	1.900	1.912
69	5.275	4.032	3.507	4.611	3.871	4.103	4.127	4.123
70	5.345	4.220	3.133	4.516	4.034	4.108	4.052	4.139
71	7.513	6.609	6.164	6.282	6.158	6.195	6.381	6.351
72	7.628	6.695	6.028	6.186	6.065	6.100	6.261	6.224
73	1.850	1.497	1.413	1.766	1.461	1.455	1.454	1.477
74	1.953	1.504	1.365	1.545	1.470	1.510	1.475	1.492
75	2.798	2.331	2.313	2.438	2.280	2.247	2.313	2.322
76	2.868	2.336	2.266	2.258	2.266	2.245	2.315	2.272
77	3.764	3.261	3.223	3.186	3.215	3.232	3.252	3.145
78	3.742	2.965	2.682	3.202	2.834	2.843	2.917	2.931
79	3.880	2.829	2.384	2.546	2.346	2.366	2.452	2.473
80	2.907	1.370	1.029	2.159	1.857	1.886	1.809	1.913
81	2.437	1.552	1.242	2.005	1.659	1.650	1.673	1.679
82	2.899	1.454	1.136	1.799	1.740	1.785	1.765	1.809
83	3.482	1.668	1.214	1.444	1.765	1.768	1.822	1.862
84	5.181	4.084	3.328	4.605	3.992	4.133	4.074	4.165
85	5.223	4.222	3.055	4.482	3.983	4.080	4.027	4.124
86	7.633	6.949	6.165	6.287	6.446	6.468	6.487	6.553
87	7.689	6.917	6.097	6.374	6.038	6.085	6.277	6.430
88	1.821	1.508	1.312	1.732	1.483	1.472	1.484	1.494
89	1.892	1.532	1.335	1.593	1.484	1.522	1.503	1.511
90	2.737	2.410	2.199	2.504	2.330	2.302	2.348	2.354
91	2.685	2.372	2.137	2.353	2.283	2.317	2.306	2.306
92	3.661	3.312	3.069	3.290	3.271	3.286	3.287	3.196
93	3.624	3.073	2.715	3.293	2.875	2.907	2.971	3.033
94	3.786	2.871	2.415	2.577	2.409	2.418	2.542	2.584

TABLE 4.3

MODEL ROOT-MEAN-SQUARE MEASUREMENTS
Heave and Wave Height at Corresponding Locations

RUN	Heave0 in	Heave2 in	Heave3 in	Heave4 in	Wave0 in	Wave2 in	Wave3 in	Wave4 in
99	2.477	1.004	0.503	1.477	1.823	1.808	2.025	1.976
100	1.984	1.384	1.239	1.923	1.549	1.614	1.617	1.705
101	1.990	1.207	0.812	1.194	1.756	1.792	1.825	1.961
102	1.344	1.035	0.942	0.533	1.401	1.449	1.562	1.815
104	5.293	3.927	3.773	4.393	3.653	3.940	4.131	4.416
105	5.873	4.389	3.096	3.716	3.791	3.893	3.928	4.136
106	8.387	6.874	5.791	8.267	6.032	6.119	6.294	6.508
107	8.397	6.966	5.511	6.810	5.759	5.774	6.149	6.198
108	1.849	1.405	1.394	1.577	1.350	1.369	1.402	1.502
109	1.794	1.421	1.194	1.306	1.194	1.233	1.301	1.341
110	2.933	2.594	2.485	2.469	2.253	2.325	2.370	2.367
111	2.854	2.513	2.204	2.612	2.316	2.301	2.354	2.430
112	3.869	3.363	3.026	3.390	3.204	3.187	3.259	3.209
113	3.565	2.842	2.694	3.342	2.544	2.568	2.627	2.677
115	2.767	2.141	1.858	2.152	1.591	1.851	2.220	1.922
116	2.100	1.397	0.822	1.478	1.774	1.844	2.081	2.163
117	2.110	1.218	1.088	1.635	1.524	1.583	1.648	1.776
118	1.655	0.988	0.883	1.000	1.553	1.611	1.669	1.835
119	1.224	0.993	1.136	0.383	1.484	1.583	1.697	1.878
120	5.202	3.705	3.780	4.425	3.489	3.815	4.032	4.368
121	5.542	4.116	3.261	4.195	3.666	3.781	3.945	3.802
122	7.608	6.269	5.784	6.700	5.971	5.982	6.208	6.521
123	8.272	6.758	5.672	6.579	5.568	5.561	5.845	6.160
124	1.777	1.645	1.592	1.540	1.326	1.332	1.385	1.464
125	1.774	1.398	1.305	1.118	1.214	1.254	1.325	1.381
126	2.925	2.327	2.448	2.278	2.315	2.338	2.408	2.415
127	2.780	2.319	2.219	2.068	2.206	2.196	2.244	2.414
128	3.880	3.263	3.130	3.104	3.132	3.142	3.269	3.204
129	3.397	2.578	2.454	2.819	2.367	2.373	2.477	2.654
130	3.161	2.434	2.245	1.948	1.655	2.001	2.495	2.080
131	2.144	1.458	0.911	1.977	1.814	1.862	2.082	2.153
132	1.948	1.223	1.080	1.717	1.434	1.540	1.589	1.695
133	1.684	1.090	1.055	1.108	1.574	1.644	1.765	1.891
134	1.080	0.888	1.157	0.545	1.451	1.529	1.740	1.914
135	5.412	3.713	3.697	4.374	3.472	3.744	4.071	4.494
136	5.855	4.030	3.391	4.153	3.631	3.728	3.865	3.758
137	7.610	6.434	6.031	7.086	5.781	5.785	6.082	6.618
139	8.820	6.814	5.925	6.147	5.256	5.295	5.620	6.179
140	1.820	1.378	1.656	1.620	1.335	1.334	1.373	1.483
141	1.783	1.327	1.365	1.117	1.173	1.211	1.321	1.379
142	3.036	2.354	2.477	2.410	2.257	2.326	2.415	2.415
143	2.910	2.350	2.203	1.956	2.211	2.189	2.268	2.415
144	3.932	3.075	3.097	3.091	3.020	3.001	3.103	3.167
145	3.431	2.528	2.800	2.870	2.351	2.359	2.524	2.676
146	3.152	2.244	2.474	1.795	1.564	2.069	2.517	1.993

TABLE 4.4

MODEL ROOT-MEAN-SQUARE MEASUREMENTS
Heave and Wave Height at Corresponding Locations

RUN	Heave0 in	Heave2 in	Heave3 in	Heave4 in	Wave0 in	Wave2 in	Wave3 in	Wave4 in
164	2.772			2.533	1.947	2.025	1.948	1.923
150	2.307			1.969	1.695	1.733	1.784	1.761
151	2.425			1.617	1.576	1.623	1.754	1.634
152	2.457			1.673	1.750	1.774	1.894	1.852
153	5.243			3.955	3.869	4.032	4.250	4.086
154	5.478			4.011	3.954	4.119	4.382	4.204
155	7.245			5.644	6.067	6.091	6.409	6.174
156	7.517			5.104	5.682	5.763	5.949	5.991
157	1.637			1.517	1.351	1.379	1.435	1.396
158	1.716			1.592	1.290	1.325	1.388	1.406
159	2.689			2.269	2.061	2.092	2.167	2.108
160	2.620			2.402	2.186	2.251	2.337	2.255
161	3.615			3.294	3.064	3.105	3.239	3.143
162	3.610			2.906	2.559	2.617	2.734	2.737
163	3.553			2.153	1.957	2.016	2.245	2.516

TABLE 5.1
1/4-SCALE MODEL HEAVE RESPONSE IN WAVES - 1 Ft x 24 Ft BOOM
RMS Heave/RMS Wave at Corresponding Locations

RUN	0	2	3	4	2H/Te rad/sec	B/W	Waves ft	Speed fps
1	1.48	0.92	0.50	1.13	5.8	34.3	R 0.5	0
2	1.42	1.02	0.70	1.08	6.2			.427
3	1.59	0.85	0.57	0.95	6.7			.839
4	1.35	0.72	0.40	0.40	7.5			1.663
5	1.44	1.09	0.89	1.14	4.5		R 1.0	.776
6	1.38	1.06	0.91	1.10	4.3			.435
7	1.39	1.06	0.85	1.13	4.5			.803
8	1.27	1.09	0.92	1.01	3.4		R 1.5	.425
9	1.31	1.14	0.92	1.06	3.5			.843
10	1.33	1.06	0.92	1.12	-		I 0.5	.416
11	1.41	1.06	1.00	1.02	-			.867
12	1.35	1.12	0.94	1.00	-		I 1.0	.420
13	1.26	1.51	1.27	1.03	-		I 0.75	.397
14	1.40	1.09	0.97	0.96	-			.829
15	1.82	1.25	0.97	1.10	-		B 1.4	.821
16	1.43	1.16	1.05	1.15	-			.393
17	1.44	1.04	0.91	1.26	5.8	10.4	R 0.5	0
18	1.42	1.02	0.71	1.01	6.2			.416
19	1.69	0.91	0.41	0.38	6.6			.801
20	1.15	0.64	0.41	0.27	7.6			1.691
21	1.41	1.02	0.89	1.04	4.3		R 1.0	.424
22	1.47	1.07	0.84	1.07	4.5			.830
23	1.19	1.06	0.98	0.89	3.4		R 1.5	.394
24	1.34	1.16	0.99	0.92	3.5			.834
25	1.36	1.16	0.99	0.91	3.5			.833
26	1.20	1.05	0.95	0.90	3.4			.440
27	1.39	1.07	0.97	1.11	-		I 0.5	.425
28	1.55	1.05	0.92	0.88	-			.872
29	1.41	1.20	0.97	0.98	-		I 0.75	.396
30	1.42	1.07	0.92	0.77	-			.825
31	1.39	1.08	0.95	1.00	-		B 1.4	.418
32	1.87	1.27	0.88	0.89	-			.824
33	1.78	1.02	0.76	1.27	5.8	4.4	R 0.5	0
34	1.47	1.00	0.75	1.09	6.3			.429
35	1.77	0.90	0.47	0.55	6.6			.798
36	0.90	0.47	0.56	0.16	7.5			1.667
37	1.82	1.07	0.92	1.00	4.3		R 1.0	.407
38	1.65	1.08	0.89	1.07	4.5			.829
39	1.25	1.06	0.98	0.90	3.4		R 1.5	.453
40	1.55	1.14	0.98	0.88	3.5			.824
41	1.50	1.09	0.96	1.06	-		I 0.5	.436
42	1.56	1.10	0.88	0.84	-			.856
43	1.62	1.09	0.98	1.03	-		I 0.75	.392
44	1.67	1.13	0.94	0.83	-			.839
45	1.67	1.09	0.95	1.03	-		B 1.4	.398
46	2.29	1.38	0.89	0.91	-			.841

TABLE 5.2

1/8-SCALE MODEL HEAVE RESPONSE IN WAVES - 0.5 Ft x 24 Ft BOOM
RMS Heave/RMS Wave at Corresponding Locations

RUN	0	2	3	4	2H/Te rad/sec	B/W	Waves ft	Speed fps
50	1.60	0.83	0.72	1.09	5.8	16.2	R 0.5	0
51	1.41	0.92	0.87	1.20	6.1			.312
52	1.96	0.99	0.85	1.05	6.5			.604
53	3.13	1.21	0.84	0.88	7.0			1.186
54	1.33	1.09	0.83	0.87	4.3		R 1.0	.303
55	1.29	1.04	0.81	0.90	4.4			.601
56	1.20	1.24	1.04	0.88	3.4		R 1.5	.312
57	1.34	1.09	1.00	0.93	3.4			.560
58	1.19	0.99	0.96	1.07	-		I 0.5	.303
59	1.38	0.99	0.93	1.01	-			.602
60	1.13	1.05	0.98	0.92	-		I 1.0	.303
61	1.21	1.05	0.98	0.98	-		I 0.75	.303
62	1.47	1.09	0.99	0.90	-			.601
63	1.41	1.10	1.00	1.02	-		B 1.4	.281
64	1.72	1.17	1.03	0.98	-			.551
65	1.66	0.83	0.79	1.30	5.8	9.6	R 0.5	0
66	1.45	0.94	0.86	1.30	6.1			.304
67	1.45	0.85	0.67	0.99	6.4			.6
68	1.99	0.86	0.48	0.65	7.0			1.182
69	1.36	0.98	0.85	1.12	4.2		R 1.0	.303
70	1.32	1.03	0.77	1.09	4.4			.601
71	1.22	1.07	0.97	0.99	3.4		R 1.5	.303
72	1.26	1.10	0.96	0.99	3.4			.601
73	1.27	1.03	0.97	1.20	-		I 0.5	.303
74	1.33	1.00	0.93	1.04	-			.602
75	1.23	1.04	1.00	1.05	-		I 0.75	.304
76	1.27	1.04	0.98	0.99	-			.587
77	1.17	1.01	0.99	1.01	-		I 1.0	.303
78	1.32	1.04	0.92	1.09	-		B 1.4	.293
79	1.65	1.20	0.97	1.03	-			.610
80	1.57	0.73	0.57	1.13	5.8	12.5	R 0.5	0
81	1.47	0.94	0.74	1.19	6.1			.295
82	1.67	0.81	0.64	0.99	6.4			.604
83	1.97	0.94	0.67	0.78	7.0			1.122
84	1.30	0.99	0.82	1.11	4.2		R 1.0	.302
85	1.31	1.03	0.76	1.09	4.4			.599
86	1.18	1.07	0.95	0.96	3.4		R 1.5	.303
87	1.27	1.14	0.97	0.99	3.4			.566
88	1.23	1.02	0.88	1.16	-		I 0.5	.304
89	1.27	1.01	0.89	1.05	-			.603
90	1.17	1.05	0.94	1.06	-		I 0.75	.303
91	1.18	1.02	0.93	1.02	-			.601
92	1.12	1.01	0.93	1.03	-		I 1.0	.304
93	1.26	1.06	0.91	1.09	-		B 1.4	.277
94	1.57	1.19	0.95	1.00	-			.619

TABLE 5.3

3/8-SCALE MODEL HEAVE RESPONSE IN WAVES - 1.5 Ft x 24 Ft BOOM
RMS Heave/RMS Wave at Corresponding Locations

RUN	0	2	3	4	2H/Te rad/sec	B/W	Waves ft	Speed fps
99	1.36	0.56	0.25	0.75	5.8	33.6	R 0.5	0
100	1.28	0.86	0.77	1.13	6.3			.489
101	1.13	0.67	0.44	0.61	6.8			.990
102	0.96	0.71	0.60	0.29	8.2			2.265
104	1.45	1.00	0.91	0.99	4.3		R 1.0	.470
105	1.55	1.13	0.79	0.90	4.3			1.084
106	1.39	1.12	0.92	1.27	4.6		R 1.5	.606
107	1.46	1.21	0.90	1.10	3.5			1.046
108	1.37	1.03	0.99	1.05	-		I 0.5	.562
109	1.50	1.15	0.92	0.97	-			1.023
110	1.30	1.12	1.05	1.04	-		I 0.75	.490
111	1.23	1.09	0.94	1.07	-			1.049
112	1.21	1.06	0.93	1.06	-		I 1.0	.509
113	1.40	1.11	1.03	1.25	-		B 1.4	.546
115	1.74	1.16	0.84	1.12	-			1.079
116	1.18	0.76	0.40	0.68	5.8	10.3	R 0.5	0
117	1.38	0.77	0.66	0.92	6.3			.490
118	1.07	0.61	0.53	0.54	6.9			1.029
119	0.82	0.63	0.67	0.20	7.8			1.950
120	1.49	0.97	0.94	1.01	4.3		R 1.0	.504
121	1.51	1.09	0.83	1.10	4.6			1.040
122	1.27	1.05	0.93	1.03	3.4		R 1.5	.559
123	1.49	1.22	0.97	1.07	3.6			1.007
124	1.34	1.23	1.15	1.05	-		I 0.5	.504
125	1.46	1.11	0.98	0.81	-			1.022
126	1.26	1.00	1.02	0.94	-		I 0.75	.503
127	1.26	1.06	0.99	0.86	-			1.020
128	1.24	1.04	0.96	0.97	-		I 1.0	.502
129	1.44	1.09	0.99	1.06	-		B 1.4	.516
130	1.91	1.22	0.90	0.94	-			1.023
131	1.18	0.78	0.44	0.92	5.8	5.0	R 0.5	0
132	1.36	0.79	0.68	1.01	6.3			.503
133	1.07	0.66	0.60	0.59	6.9			1.037
134	0.74	0.58	0.66	0.28	7.8			1.928
135	1.56	0.99	0.91	0.97	4.4		R 1.0	.541
136	1.61	1.08	0.88	1.11	4.6			1.019
137	1.32	1.11	0.99	1.07	3.4		R 1.5	.546
139	1.68	1.29	1.05	0.99	3.6			1.013
140	1.36	1.03	1.21	1.09	-		R 0.5	.527
141	1.52	1.10	1.03	0.81	-			1.039
142	1.35	1.01	1.03	1.00	-		I 0.75	.501
143	1.32	1.07	0.97	0.81	-			1.028
144	1.30	1.02	1.00	0.98	-		I 1.0	.538
145	1.46	1.07	1.11	1.07	-		B 1.4	.538
146	2.02	1.08	0.98	0.90	-			1.029

TABLE 5.4

1/4-SCALE MODEL HEAVE RESPONSE IN WAVES - 1 Ft x 12 Ft BOOM
 RMS Heave/RMS Wave at Corresponding Locations

RUN	0	2	3	4	$2\pi/T_e$ rad/sec	B/W	Waves ft	Speed fps
164	1.42	-	-	1.32	5.8	9.9	R 0.5	0
150	1.36	-	-	1.12	6.3			.470
151	1.54	-	-	0.99	6.6			.769
152	1.40	-	-	0.90	7.5			1.577
153	1.36	-	-	0.97	4.3		R 1.0	.469
154	1.39	-	-	0.95	4.5			.805
155	1.19	-	-	0.91	3.4		R 1.5	.429
156	1.32	-	-	0.85	3.5			.850
157	1.21	-	-	1.09	-		I 0.5	.433
158	1.33	-	-	1.13	-			.829
159	1.30	-	-	1.08	-		I 0.75	.421
160	1.20	-	-	1.07	-			.850
161	1.18	-	-	1.05	-		I 1.0	.417
162	1.41	-	-	1.06	-		B 1.4	.425
163	1.82	-	-	0.86	-			.847

TABLE 6.1

MODEL IRREGULAR WAVE TEST RESULTS

Boom 0.5 x 24 ft B/W = 16.2

Waves 0.50 ft Significant Height

Run(s) : 58, Speed 0.303 fps

	Mean/RMS	Osc/Buf	Avg	1/3	1/10	Extreme
Heave 0, in	0.611 1.762	177 0.30	2.69 -1.34	4.48 -2.67	5.64 -3.48	6.37 -5.53
Heave 2, in	-0.141 1.465	147 0.30	1.59 -1.84	2.94 -3.00	3.76 -3.76	4.30 -4.96
Heave 3, in	0.480 1.416	148 0.30	2.25 -1.12	3.60 -2.16	4.48 -2.80	5.97 -3.43
Heave 4, in	-0.068 1.610	178 0.30	1.83 -1.88	3.16 -3.22	3.95 -4.22	4.74 -5.76
Wave 0, in	-0.372 1.486	168 0.30	1.54 -1.92	2.92 -3.17	3.79 -3.95	4.31 -5.72
Wave 2, in	-0.257 1.484	170 0.30	1.55 -1.87	2.90 -3.11	3.78 -3.84	4.69 -5.36
Wave 3, in	-0.255 1.474	174 0.30	1.49 -1.82	2.93 -3.01	3.87 -3.78	6.04 -4.34
Wave 4, in	-0.348 1.499	175 0.30	1.49 -1.87	2.79 -3.19	3.81 -3.99	5.27 -5.03

TABLE 6.2

MODEL IRREGULAR WAVE TEST RESULTS

Boom 0.5 x 24 ft B/W = 16.2

Waves 0.50 ft Significant Height

Run(s) : 59, Speed 0.602 fps

	Mean/RMS	Osc/Buf	Avg	1/3	1/10	Extreme
Heave 0, in	0.832 2.068	97 0.30	3.13 -1.34	4.79 -3.13	6.44 -5.13	7.85 -10.40
Heave 2, in	0.059 1.500	77 0.30	1.84 -1.63	3.20 -2.92	4.41 -3.84	5.28 -5.01
Heave 3, in	0.343 1.388	77 0.30	2.07 -1.22	3.29 -2.31	4.29 -2.89	5.28 -3.54
Heave 4, in	0.207 1.499	100 0.30	1.81 -1.44	3.11 -2.62	4.00 -3.32	4.71 -4.06
Wave 0, in	-0.401 1.501	89 0.30	1.40 -2.07	2.73 -3.28	4.17 -4.06	5.38 -4.59
Wave 2, in	-0.279 1.519	84 0.30	1.64 -1.98	2.96 -3.07	4.31 -3.59	5.80 -4.16
Wave 3, in	-0.285 1.496	83 0.30	1.68 -1.99	2.99 -3.20	3.95 -3.93	4.55 -4.30
Wave 4, in	-0.406 1.489	88 0.30	1.47 -2.04	2.72 -3.27	3.60 -4.18	4.31 -4.92

TABLE 6.3

MODEL IRREGULAR WAVE TEST RESULTS
 Boom 0.5 x 24 ft B/W = 16.2
 Waves 0.75 ft Significant Height

Run(s) : 61, Speed 0.303 fps

	Mean/RMS	Osc/Buf	Avg	1/3	1/10	Extreme
Heave 0, in	0.702 2.777	160 0.30	3.77 -1.88	6.57 -4.12	8.41 -6.25	11.51 -14.60
Heave 2, in	-0.035 2.374	127 0.30	2.79 -2.58	4.91 -4.25	6.40 -5.87	8.36 -9.86
Heave 3, in	0.308 2.253	126 0.30	3.07 -2.12	5.14 -3.78	6.67 -5.41	9.49 -8.57
Heave 4, in	-0.140 2.263	171 0.30	2.20 -2.41	4.26 -4.39	5.50 -5.74	7.88 -9.55
Wave 0, in	-0.385 2.302	141 0.30	2.42 -2.74	4.59 -4.43	6.14 -5.83	7.98 -9.28
Wave 2, in	-0.273 2.270	138 0.30	2.57 -2.61	4.75 -4.37	6.46 -5.86	9.66 -9.10
Wave 3, in	-0.275 2.306	146 0.30	2.40 -2.50	4.49 -4.42	6.50 -5.62	10.13 -9.05
Wave 4, in	-0.374 2.317	142 0.30	2.49 -2.74	4.52 -4.62	6.36 -6.06	9.95 -8.76

TABLE 6.4

MODEL IRREGULAR WAVE TEST RESULTS
 Boom 0.5 x 24 ft B/W = 16.2
 Waves 0.75 ft Significant Height

Run(s) : 62, Speed 0.601 fps

	Mean/RMS	Osc/Buff	Avg	1/3	1/10	Extreme
Heave 0, in	0.517 3.246	85 0.30	3.75 -2.21	6.43 -5.12	8.18 -9.80	11.40 -17.95
Heave 2, in	0.434 2.441	66 0.30	3.22 -2.19	5.32 -3.96	6.88 -6.04	9.18 -11.28
Heave 3, in	-0.100 2.301	65 0.30	2.65 -2.58	4.68 -4.20	6.62 -5.68	10.30 -8.23
Heave 4, in	0.539 2.072	94 0.30	2.47 -1.53	4.22 -3.52	5.58 -4.91	6.92 -7.29
Wave 0, in	-0.293 2.214	76 0.30	2.22 -2.53	4.52 -4.12	6.12 -5.47	8.85 -9.26
Wave 2, in	-0.150 2.249	71 0.30	2.57 -2.49	4.66 -4.11	6.20 -5.24	8.62 -8.78
Wave 3, in	-0.198 2.324	72 0.30	2.65 -2.62	4.70 -4.47	6.40 -5.77	10.23 -9.48
Wave 4, in	-0.353 2.294	75 0.30	2.30 -2.69	4.20 -4.58	5.90 -5.92	10.69 -8.29

TABLE 6.5

MODEL IRREGULAR WAVE TEST RESULTS

Boom 0.5 x 24 ft B/W = 16.2

Waves 1.00 ft Significant Height

Run(s) : 60, Speed 0.303 fps

	Mean/RMS	Osc/Buff	Avg	1/3	1/10	Extreme
Heave 0, in	0.162 3.647	139 0.30	4.11 -3.31	7.39 -6.33	9.49 -9.00	11.64 -15.03
Heave 2, in	-0.274 3.382	112 0.30	3.92 -4.03	6.77 -6.70	8.54 -8.43	10.86 -10.15
Heave 3, in	0.233 3.192	119 0.30	4.10 -2.98	6.90 -5.63	8.80 -7.36	10.78 -9.07
Heave 4, in	-0.306 2.867	145 0.30	2.79 -3.22	5.26 -5.63	6.44 -7.04	8.11 -8.60
Wave 0, in	-0.432 3.216	132 0.30	3.37 -3.57	6.27 -6.23	7.93 -7.68	9.59 -9.25
Wave 2, in	-0.311 3.232	127 0.30	3.55 -3.56	6.49 -6.16	8.34 -7.80	10.07 -10.13
Wave 3, in	-0.318 3.264	128 0.30	3.61 -3.56	6.55 -6.30	8.30 -7.93	9.80 -8.99
Wave 4, in	-0.406 3.132	126 0.30	3.61 -3.63	6.30 -6.05	7.83 -7.74	9.52 -8.95

TABLE 6.6

MODEL BREAKING WAVE TEST RESULTS

Boom 0.5 x 24 ft B/W = 16.2

Waves 1.4 ft Significant Height

Run(s) : 63, Speed 0.281 fps

	Mean/RMS	Osc/Buf	Avg	1/3	1/10	Extreme
Heave 0, in	0.192 3.860	153 0.30	5.03 -3.61	8.75 -6.82	11.17 -11.04	13.58 -15.35
Heave 2, in	-0.097 3.019	151 0.30	3.71 -3.48	6.45 -5.80	8.37 -6.89	9.65 -9.23
Heave 3, in	-0.221 2.798	151 0.30	3.46 -3.42	6.07 -5.60	7.91 -6.68	9.29 -8.48
Heave 4, in	-0.041 2.892	160 0.30	3.59 -3.45	5.66 -5.77	6.51 -7.61	7.64 -9.62
Wave 0, in	-0.266 2.744	152 0.30	3.64 -3.44	6.26 -5.29	8.38 -6.72	10.38 -7.55
Wave 2, in	-0.137 2.740	152 0.30	3.76 -3.30	6.43 -5.17	8.42 -6.51	10.09 -7.58
Wave 3, in	-0.165 2.803	152 0.30	3.82 -3.36	6.54 -5.36	8.49 -6.66	10.21 -7.42
Wave 4, in	-0.295 2.830	154 0.30	3.67 -3.53	6.45 -5.55	8.69 -6.79	10.30 -8.04

TABLE 6.7

MODEL BREAKING WAVE TEST RESULTS

Boom 0.5 x 24 ft B/W = 16.2

Waves 1.4 ft Significant Height

Run(s) : 64, Speed 0.551 fps

	Mean/RMS	Osc/Buff	Avg	1/3	1/10	Extreme
Heave 0, in	-0.304 4.434	79 0.30	4.74 -3.78	8.53 -9.12	11.00 -17.03	13.25 -18.31
Heave 2, in	-0.168 3.052	75 0.30	3.54 -3.39	6.46 -6.42	8.71 -9.63	10.34 -11.19
Heave 3, in	-0.409 2.746	73 0.30	3.01 -3.69	6.03 -5.93	8.13 -6.86	9.36 -7.34
Heave 4, in	0.216 2.607	83 0.30	3.19 -2.82	5.46 -5.38	6.34 -7.43	6.71 -9.04
Wave 0, in	-0.306 2.584	77 0.30	3.19 -3.17	6.21 -5.43	8.22 -7.07	9.73 -7.67
Wave 2, in	-0.176 2.598	77 0.30	3.35 -3.03	6.46 -5.35	8.61 -6.93	10.74 -7.65
Wave 3, in	-0.224 2.668	78 0.30	3.42 -3.12	6.44 -5.41	8.62 -6.81	10.33 -7.59
Wave 4, in	-0.358 2.662	77 0.30	3.30 -3.32	6.31 -5.64	8.34 -6.70	9.81 -7.08

TABLE 6.8

MODEL IRREGULAR WAVE TEST RESULTS

Boom 0.5 x 24 ft B/W = 12.5

Waves 0.50 ft Significant Height

Run(s) : 88, Speed 0.304 fps

	Mean/RMS	Osc/Buff	Avg	1/3	1/10	Extreme
Heave 0, in	0.145 1.821	180 0.30	2.26 -1.90	3.95 -3.39	5.04 -4.32	6.05 -5.23
Heave 2, in	1.573 1.508	152 0.30	3.37 -0.17	4.72 -1.43	5.56 -2.20	6.10 -3.74
Heave 3, in	1.200 1.312	140 0.30	2.84 -0.31	4.13 -1.31	4.80 -1.91	5.59 -2.49
Heave 4, in	0.689 1.732	172 0.30	2.65 -1.24	4.32 -2.63	5.30 -3.55	6.77 -4.37
Wave 0, in	-0.191 1.483	166 0.30	1.65 -1.81	2.92 -3.07	3.87 -3.85	5.02 -5.09
Wave 2, in	-0.049 1.472	164 0.30	1.81 -1.66	3.22 -2.81	4.04 -3.62	4.59 -5.24
Wave 3, in	-0.097 1.484	170 0.30	1.70 -1.68	3.13 -2.90	4.01 -3.53	5.29 -4.88
Wave 4, in	-0.238 1.494	170 0.30	1.61 -1.84	3.01 -3.07	3.91 -3.83	5.29 -4.59

TABLE 6.9

MODEL IRREGULAR WAVE TEST RESULTS
 Boom 0.5 x 24 ft B/W = 12.5
 Waves 0.50 ft Significant Height

Run(s) : 89, Speed 0.603 fps

	Mean/RMS	Osc/Buf	Avg	1/3	1/10	Extreme
Heave 0, in	0.157 1.892	93 0.30	2.48 -1.93	4.10 -3.40	5.33 -4.47	6.45 -5.45
Heave 2, in	1.727 1.532	80 0.30	3.51 -0.05	4.86 -1.30	5.97 -2.10	6.64 -2.39
Heave 3, in	1.145 1.335	74 0.30	2.81 -0.35	3.96 -1.47	4.84 -2.05	5.89 -2.73
Heave 4, in	0.893 1.593	95 0.30	2.63 -0.95	4.12 -2.16	5.21 -2.88	5.79 -4.20
Wave 0, in	-0.195 1.484	86 0.30	1.70 -1.76	2.99 -2.95	3.95 -3.86	4.54 -5.03
Wave 2, in	-0.044 1.522	86 0.30	1.80 -1.77	3.22 -2.95	4.47 -3.72	6.09 -4.23
Wave 3, in	-0.108 1.503	85 0.30	1.80 -1.83	3.15 -2.96	4.25 -3.44	5.58 -3.92
Wave 4, in	-0.269 1.511	90 0.30	1.54 -1.88	2.80 -3.19	3.71 -4.14	4.30 -5.09

TABLE 6.10

MODEL IRREGULAR WAVE TEST RESULTS

Boom 0.5 x 24 ft B/W = 12.5

Waves 0.75 ft Significant Height

Run(s) : 90, Speed 0.303 fps

	Mean/RMS	Osc/Buff	Avg	1/3	1/10	Extreme
Heave 0, in	0.101 2.737	161 0.30	3.22 -2.44	6.19 -4.60	8.23 -6.34	10.84 -10.99
Heave 2, in	1.450 2.410	128 0.30	4.39 -1.19	6.58 -3.03	8.07 -4.60	9.88 -8.05
Heave 3, in	0.934 2.199	121 0.30	3.69 -1.48	5.74 -3.13	7.55 -4.56	10.40 -6.64
Heave 4, in	0.642 2.504	159 0.30	3.34 -1.94	5.74 -3.98	7.55 -5.46	10.08 -8.26
Wave 0, in	-0.198 2.330	145 0.30	2.54 -2.54	4.80 -4.27	6.33 -5.79	8.26 -9.21
Wave 2, in	-0.060 2.302	145 0.30	2.70 -2.32	4.93 -4.14	6.49 -5.51	8.40 -9.05
Wave 3, in	-0.096 2.348	145 0.30	2.73 -2.44	4.80 -4.38	6.67 -5.74	10.15 -9.10
Wave 4, in	-0.242 2.354	146 0.30	2.58 -2.59	4.69 -4.56	6.55 -6.04	9.94 -9.08

TABLE 6.11

MODEL IRREGULAR WAVE TEST RESULTS

Boom 0.5 x 24 ft B/W = 12.5

Waves 0.75 ft Significant Height

Run(s) : 91, Speed 0.601 fps

	Mean/RMS	Osc/Buff	Avg	1/3	1/10	Extreme
Heave 0, in	0.041 2.685	87 0.30	3.15 -2.42	6.02 -4.58	7.90 -5.99	10.03 -9.39
Heave 2, in	1.565 2.372	72 0.30	4.30 -0.95	6.66 -2.64	8.40 -4.06	11.62 -7.76
Heave 3, in	0.973 2.137	64 0.30	3.66 -1.28	5.76 -2.69	7.27 -4.21	10.51 -8.21
Heave 4, in	0.807 2.353	87 0.30	3.15 -1.69	5.65 -3.59	7.11 -4.97	8.27 -6.64
Wave 0, in	-0.231 2.283	75 0.30	2.38 -2.56	4.33 -4.34	5.63 -5.67	8.25 -8.69
Wave 2, in	-0.074 2.317	75 0.30	2.69 -2.48	4.99 -4.23	6.91 -5.71	10.38 -8.94
Wave 3, in	-0.150 2.306	78 0.30	2.56 -2.34	4.85 -4.13	6.84 -5.68	10.11 -9.60
Wave 4, in	-0.292 2.306	75 0.30	2.38 -2.52	4.38 -4.30	5.76 -5.57	6.42 -6.73

TABLE 6.12

MODEL IRREGULAR WAVE TEST RESULTS

Boom 0.5 x 24 ft B/W = 12.5

Waves 1.00 ft Significant Height

Run(s) : 92, Speed 0.304 fps

	Mean/RMS	Osc/Buf	Avg	1/3	1/10	Extreme
Heave 0, in	0.025 3.661	133 0.30	4.28 -3.58	7.69 -6.55	9.54 -8.57	11.56 -11.63
Heave 2, in	1.439 3.312	113 0.30	5.52 -2.25	8.27 -4.85	9.74 -6.40	10.22 -7.18
Heave 3, in	0.653 3.069	114 0.30	4.39 -2.58	7.05 -5.08	8.59 -6.86	10.43 -7.93
Heave 4, in	0.557 3.290	143 0.30	4.12 -2.88	7.32 -5.40	8.95 -7.11	10.73 -8.36
Wave 0, in	-0.233 3.271	131 0.30	3.61 -3.40	6.63 -6.14	8.36 -7.62	9.37 -9.47
Wave 2, in	-0.078 3.286	126 0.30	3.97 -3.27	6.78 -6.00	8.79 -7.79	11.03 -10.00
Wave 3, in	-0.124 3.287	133 0.30	3.60 -3.33	6.63 -6.11	8.29 -7.76	9.79 -9.25
Wave 4, in	-0.261 3.196	128 0.30	3.75 -3.48	6.61 -6.00	8.41 -7.83	9.36 -9.13

TABLE 6.13

MODEL BREAKING WAVE TEST RESULTS

Boom 0.5 x 24 ft B/W = 12.5

Waves 1.4 ft Significant Height

Run(s) : 93, SPEED 0.277 fps

	Mean/RMS	Osc/Buff	Avg	1/3	1/10	Extreme
Heave 0, in	-0.119 3.624	144 0.30	4.83 -3.99	8.16 -7.01	9.91 -9.81	11.89 -12.83
Heave 2, in	1.010 3.073	133 0.30	5.14 -2.75	7.93 -4.87	9.39 -6.03	10.21 -7.56
Heave 3, in	0.425 2.715	140 0.30	3.93 -2.82	6.75 -4.32	8.58 -5.21	10.36 -6.67
Heave 4, in	0.237 3.293	145 0.30	4.55 -3.61	7.25 -5.81	8.16 -7.26	9.20 -8.67
Wave 0, in	-0.233 2.875	134 0.30	3.98 -3.64	6.65 -5.61	8.88 -6.98	10.43 -8.29
Wave 2, in	-0.087 2.907	135 0.30	4.12 -3.49	6.90 -5.44	9.36 -6.84	10.88 -8.16
Wave 3, in	-0.124 2.971	135 0.30	4.20 -3.58	6.94 -5.65	9.32 -6.98	10.87 -8.08
Wave 4, in	-0.266 3.033	135 0.30	4.09 -3.81	7.11 -5.99	9.04 -7.50	10.31 -8.17

TABLE 6.14

MODEL BREAKING WAVE TEST RESULTS

Boom 0.5 x 24 ft B/W = 12.5

Waves 1.4 ft Significant Height

Run(s) : 94, Speed 0.619 fps

	Mean/RMS	Osc/Buf	Avg	1/3	1/10	Extreme
Heave 0, in	-0.397 3.786	70 0.30	3.92 -4.12	7.50 -8.38	9.86 -14.25	12.02 -17.74
Heave 2, in	1.269 2.871	60 0.30	5.07 -2.34	7.74 -5.38	9.94 -8.37	10.25 -9.90
Heave 3, in	0.732 2.415	66 0.30	3.78 -2.12	6.65 -4.32	9.00 -5.56	10.32 -7.58
Heave 4, in	0.686 2.577	81 0.30	3.46 -2.22	6.32 -4.63	7.69 -5.66	8.49 -6.65
Wave 0, in	-0.203 2.409	67 0.30	3.03 -2.85	6.00 -5.16	8.32 -6.77	10.94 -7.60
Wave 2, in	-0.056 2.418	67 0.30	3.16 -2.71	6.16 -5.10	8.45 -6.65	10.83 -7.42
Wave 3, in	-0.105 2.542	68 0.30	3.22 -2.91	6.23 -5.35	8.81 -6.73	10.36 -7.12
Wave 4, in	-0.285 2.584	71 0.30	3.09 -3.05	6.28 -5.52	8.79 -6.87	10.00 -8.64

TABLE 6.15

MODEL IRREGULAR WAVE TEST RESULTS
 Boom 0.5 x 24 ft B/W = 9.6
 Waves 0.50 ft Significant Height

Run(s) : 73, Speed 0.303 fps

	Mean/RMS	Osc/Buff	Avg	1/3	1/10	Extreme
Heave 0, in	0.045 1.850	185 0.30	2.20 -2.01	3.88 -3.52	4.90 -4.47	6.11 -5.43
Heave 2, in	1.457 1.497	152 0.30	3.28 -0.33	4.55 -1.55	5.36 -2.27	5.91 -3.68
Heave 3, in	0.892 1.413	147 0.30	2.63 -0.71	3.93 -1.74	4.72 -2.36	5.62 -2.96
Heave 4, in	0.403 1.766	174 0.30	2.38 -1.61	3.99 -3.05	4.96 -4.06	6.67 -5.15
Wave 0, in	-0.258 1.461	166 0.30	1.52 -1.89	2.71 -3.11	3.53 -3.87	4.79 -5.18
Wave 2, in	-0.133 1.455	165 0.30	1.67 -1.73	2.92 -2.96	3.88 -3.80	4.37 -4.98
Wave 3, in	-0.142 1.454	169 0.30	1.60 -1.71	3.04 -2.86	4.04 -3.44	5.00 -4.85
Wave 4, in	-0.235 1.477	169 0.30	1.56 -1.83	2.97 -3.02	3.91 -3.80	5.36 -4.59

TABLE 6.16

MODEL IRREGULAR WAVE TEST RESULTS

Boom 0.5 x 24 ft B/W = 9.6

Waves 0.50 ft Significant Height

Run(s) : 74, Speed 0.602 fps

	Mean/RMS	Osc/Buff	Avg	1/3	1/10	Extreme
Heave 0, in	-0.007 1.953	95 0.30	2.29 -2.21	4.10 -3.70	5.45 -4.66	6.02 -5.46
Heave 2, in	1.519 1.504	79 0.30	3.34 -0.25	4.64 -1.42	5.83 -2.15	6.45 -2.46
Heave 3, in	0.920 1.365	76 0.30	2.59 -0.62	3.89 -1.60	4.80 -2.19	5.73 -2.43
Heave 4, in	0.619 1.545	96 0.30	2.25 -1.18	3.60 -2.30	4.71 -3.17	5.35 -4.34
Wave 0, in	-0.308 1.470	88 0.30	1.51 -1.89	2.78 -3.09	4.00 -3.91	5.16 -4.46
Wave 2, in	-0.174 1.510	88 0.30	1.61 -1.92	2.99 -3.09	4.29 -3.77	6.25 -4.49
Wave 3, in	-0.199 1.475	86 0.30	1.69 -1.81	2.98 -2.96	4.07 -3.56	4.74 -3.84
Wave 4, in	-0.315 1.492	90 0.30	1.49 -1.92	2.75 -3.23	3.63 -4.14	4.38 -4.94

TABLE 6.17

MODEL IRREGULAR WAVE TEST RESULTS

Boom 0.5 x 24 ft B/W = 9.6

Waves 0.75 ft Significant Height

Run(s) : 75, Speed 0.304 fps

	Mean/RMS	Osc/Buff	Avg	1/3	1/10	Extreme
Heave 0, in	0.020 2.798	160 0.30	3.13 -2.66	6.08 -4.78	8.00 -6.76	10.06 -15.12
Heave 2, in	1.423 2.331	128 0.30	4.26 -1.14	6.42 -2.84	8.08 -4.47	9.97 -8.11
Heave 3, in	0.666 2.313	130 0.30	3.48 -1.88	5.60 -3.51	7.41 -4.79	10.57 -7.32
Heave 4, in	0.677 2.438	168 0.30	3.17 -1.72	5.54 -3.70	7.40 -4.98	9.88 -7.61
Wave 0, in	-0.331 2.280	143 0.30	2.41 -2.61	4.62 -4.35	6.00 -5.75	8.12 -8.95
Wave 2, in	-0.203 2.247	146 0.30	2.45 -2.41	4.69 -4.21	6.20 -5.49	8.57 -8.70
Wave 3, in	-0.251 2.313	147 0.30	2.49 -2.50	4.56 -4.42	6.55 -5.75	10.55 -9.30
Wave 4, in	-0.389 2.322	147 0.30	2.35 -2.69	4.43 -4.63	6.36 -6.10	9.55 -8.89

TABLE 6.18

MODEL IRREGULAR WAVE TEST RESULTS

Boom 0.5 x 24 ft B/W = 9.6

Waves 0.75 ft Significant Height

Run(s) : 76, Speed 0.587 fps

	Mean/RMS	Osc/Buf	Avg	1/3	1/10	Extreme
Heave 0, in	-0.159 2.868	75 0.30	3.32 -3.08	5.58 -5.47	7.62 -8.12	10.74 -14.78
Heave 2, in	1.433 2.336	67 0.30	4.19 -1.19	6.10 -2.96	7.98 -4.36	10.67 -7.75
Heave 3, in	0.725 2.266	65 0.30	3.57 -1.79	5.34 -3.51	7.13 -5.04	11.28 -6.77
Heave 4, in	0.827 2.258	88 0.30	2.99 -1.55	5.28 -3.40	6.92 -5.13	11.36 -7.20
Wave 0, in	-0.338 2.266	70 0.30	2.45 -2.84	4.43 -4.56	6.09 -5.64	8.85 -8.54
Wave 2, in	-0.206 2.245	70 0.30	2.57 -2.68	4.42 -4.41	6.28 -5.54	10.12 -8.53
Wave 3, in	-0.259 2.315	73 0.30	2.55 -2.67	4.50 -4.56	6.18 -5.84	10.05 -8.83
Wave 4, in	-0.389 2.272	75 0.30	2.32 -2.74	4.14 -4.56	5.77 -6.20	11.35 -7.25

TABLE 6.19

MODEL IRREGULAR WAVE TEST RESULTS
 Boom 0.5 x 24 ft B/W = 9.6
 Waves 1.00 ft Significant Height

Run(s) : 77, Speed 0.303 fps

	Mean/RMS	Osc/Buff	Avg	1/3	1/10	Extreme
Heave 0, in	-0.097 3.764	136 0.30	4.15 -3.66	7.49 -6.72	9.66 -8.87	10.90 -12.11
Heave 2, in	1.402 3.261	116 0.30	5.38 -2.09	8.18 -4.64	9.93 -6.25	10.97 -7.13
Heave 3, in	0.671 3.223	118 0.30	4.58 -2.84	7.47 -5.49	9.20 -7.06	10.67 -8.53
Heave 4, in	0.654 3.186	147 0.30	4.15 -2.65	7.16 -5.15	8.70 -6.62	10.68 -8.48
Wave 0, in	-0.318 3.215	131 0.30	3.45 -3.52	6.47 -6.08	8.20 -7.64	9.20 -8.70
Wave 2, in	-0.174 3.232	129 0.30	3.72 -3.34	6.61 -5.92	8.50 -7.62	10.20 -9.69
Wave 3, in	-0.232 3.252	127 0.30	3.63 -3.53	6.64 -6.19	8.35 -7.97	9.95 -9.39
Wave 4, in	-0.373 3.145	126 0.30	3.53 -3.65	6.34 -6.09	7.83 -7.71	9.02 -9.56

TABLE 6.20

MODEL BREAKING WAVE TEST RESULTS

Boom 0.5 x 24 ft B/W = 9.6

Waves 1.4 ft Significant Height

Run(s) : 78, Speed 0.293 fps

	Mean/RMS	Osc/Buff	Avg	1/3	1/10	Extreme
Heave 0, in	-0.227 3.742	148 0.30	4.92 -4.19	8.05 -7.47	9.67 -11.10	12.05 -15.50
Heave 2, in	1.030 2.965	142 0.30	4.92 -2.53	7.48 -4.74	8.81 -6.10	9.85 -8.75
Heave 3, in	0.416 2.682	149 0.30	4.01 -2.73	6.57 -4.34	8.34 -5.22	9.49 -6.66
Heave 4, in	0.077 3.202	148 0.30	4.32 -3.71	7.02 -5.87	8.01 -7.20	8.79 -9.53
Wave 0, in	-0.259 2.834	142 0.30	3.89 -3.64	6.64 -5.51	8.89 -6.81	9.98 -8.05
Wave 2, in	-0.129 2.843	146 0.30	3.87 -3.49	6.74 -5.36	9.08 -6.61	11.04 -7.62
Wave 3, in	-0.191 2.917	146 0.30	3.97 -3.61	6.72 -5.67	8.75 -6.97	9.90 -7.84
Wave 4, in	-0.341 2.931	143 0.30	3.92 -3.82	6.82 -5.93	8.87 -7.14	10.23 -8.15

TABLE 6.21

MODEL BREAKING WAVE TEST RESULTS

Boom 0.5 x 24 ft B/W = 9.6

Waves 1.4 ft Significant Height

Run(s) : 79, Speed 0.610 fps

	Mean/RMS	Osc/Buff	Avg	1/3	1/10	Extreme
Heave 0, in	-0.557 3.880	72 0.30	3.79 -4.12	7.27 -8.78	9.88 -15.28	12.15 -18.20
Heave 2, in	1.336 2.829	58 0.30	5.21 -2.34	7.79 -5.55	9.43 -8.87	9.90 -9.42
Heave 3, in	0.598 2.384	58 0.30	4.29 -2.43	7.01 -4.41	8.84 -5.72	9.52 -6.77
Heave 4, in	0.640 2.546	78 0.30	3.44 -2.19	6.41 -4.52	7.69 -6.05	8.27 -6.63
Wave 0, in	-0.185 2.346	67 0.30	2.88 -2.78	5.71 -5.14	7.66 -6.71	9.77 -7.21
Wave 2, in	-0.050 2.366	69 0.30	3.00 -2.55	5.82 -4.96	8.14 -6.65	9.94 -7.53
Wave 3, in	-0.121 2.452	69 0.30	3.09 -2.77	5.99 -5.15	8.47 -6.61	9.99 -7.39
Wave 4, in	-0.282 2.473	65 0.30	3.15 -3.15	6.34 -5.57	8.90 -6.80	9.68 -7.79

TABLE 6.22

MODEL IRREGULAR WAVE TEST RESULTS

Boom 1 x 24 ft B/W = 34.3

Waves 0.50 ft Significant Height

Run(s) : 10, Speed 0.416 fps

	Mean/RMS	Osc/Buf	Avg	1/3	1/10	Extreme
Heave 0, in	0.228 1.763	126 0.30	2.24 -1.81	3.71 -3.31	4.61 -4.36	5.51 -5.95
Heave 2, in	0.145 1.420	112 0.30	1.90 -1.50	3.08 -2.76	3.75 -3.63	4.76 -4.64
Heave 3, in	0.580 1.247	102 0.30	2.15 -0.86	3.08 -1.89	3.61 -2.49	4.41 -2.74
Heave 4, in	1.336 1.537	124 0.30	3.15 -0.48	4.32 -1.62	5.20 -2.39	6.70 -2.88
Wave 0, in	-0.320 1.326	126 0.30	1.32 -1.78	2.47 -2.82	3.23 -3.51	4.60 -4.39
Wave 2, in	-0.225 1.338	130 0.30	1.39 -1.70	2.56 -2.72	3.41 -3.32	5.97 -4.18
Wave 3, in	-0.218 1.360	131 0.30	1.45 -1.64	2.62 -2.74	3.46 -3.20	5.65 -3.90
Wave 4, in	-0.291 1.375	131 0.30	1.37 -1.78	2.63 -2.87	3.44 -3.71	4.81 -4.69

TABLE 6.23

MODEL IRREGULAR WAVE TEST RESULTS

Boom 1 x 24 ft B/W = 34.3

Waves 0.50 ft Significant Height

Run(s) : 11, Speed 0.867 fps

	Mean/RMS	Osc/Buf	Avg	1/3	1/10	Extreme
Heave 0, in	0.115 1.912	65 0.30	2.33 -2.05	3.64 -3.77	4.64 -5.27	5.28 -5.92
Heave 2, in	-0.217 1.474	56 0.30	1.54 -1.92	2.83 -3.22	3.86 -4.26	4.60 -5.01
Heave 3, in	0.230 1.403	51 0.30	1.97 -1.40	3.11 -2.60	3.94 -3.42	4.67 -4.13
Heave 4, in	1.793 1.496	69 0.30	3.30 0.16	4.38 -1.31	5.10 -2.84	5.71 -4.80
Wave 0, in	-0.396 1.357	66 0.30	1.16 -1.82	2.21 -2.98	3.13 -3.78	4.21 -3.98
Wave 2, in	-0.297 1.395	63 0.30	1.36 -1.87	2.46 -3.02	3.45 -3.69	5.03 -3.91
Wave 3, in	-0.303 1.404	67 0.30	1.41 -1.74	2.73 -2.78	3.71 -3.63	4.36 -4.13
Wave 4, in	-0.387 1.465	69 0.30	1.32 -1.87	2.46 -3.10	3.42 -4.16	3.73 -5.32

TABLE 6.24

MODEL IRREGULAR WAVE TEST RESULTS

Boom 1 x 24 ft B/W = 34.3

Waves 0.75 ft Significant Height

Run(s) : 13, Speed 0.397 fps

	Mean/RMS	Osc/Buff	Avg	1/3	1/10	Extreme
Heave 0, in	-0.022 2.706	109 0.30	3.11 -2.91	5.42 -5.07	7.11 -6.77	11.28 -10.79
Heave 2, in	-0.529 3.244	102 0.30	2.15 -3.04	4.67 -5.81	6.41 -10.30	11.09 -15.52
Heave 3, in	0.186 2.825	95 0.30	2.85 -2.19	4.98 -4.75	6.60 -8.73	12.10 -13.26
Heave 4, in	0.951 2.268	124 0.30	3.29 -1.32	5.46 -3.36	7.02 -5.27	11.44 -8.82
Wave 0, in	-0.319 2.140	109 0.30	2.28 -2.51	4.40 -4.07	6.16 -5.19	13.01 -7.47
Wave 2, in	-0.233 2.146	103 0.30	2.52 -2.58	4.51 -4.18	6.42 -5.27	12.80 -7.38
Wave 3, in	-0.227 2.223	110 0.30	2.50 -2.43	4.43 -4.16	6.07 -5.51	12.24 -7.06
Wave 4, in	-0.321 2.194	108 0.30	2.43 -2.60	4.34 -4.25	6.00 -5.62	11.34 -8.50

TABLE 6.25

MODEL IRREGULAR WAVE TEST RESULTS
 Boom 1 x 24 ft B/W = 34.3
 Waves 0.75 ft Significant Height

Run(s) : 14, Speed 0.821 fps

	Mean/RMS	Osc/Buff	Avg	1/3	1/10	Extreme
Heave 0, in	0.049 3.072	58 0.30	3.39 -2.81	5.80 -5.57	7.59 -8.90	11.04 -18.60
Heave 2, in	-0.187 2.421	47 0.30	2.77 -2.90	4.66 -4.90	6.90 -6.99	10.34 -11.82
Heave 3, in	0.322 2.180	42 0.30	3.18 -2.51	4.72 -4.02	6.64 -5.69	10.19 -7.51
Heave 4, in	2.008 2.227	66 0.30	3.99 -0.20	5.82 -2.36	7.09 -4.17	7.58 -8.00
Wave 0, in	-0.389 2.192	52 0.30	2.40 -2.55	4.12 -4.38	5.78 -5.60	8.48 -8.36
Wave 2, in	-0.284 2.229	53 0.30	2.39 -2.65	4.28 -4.34	6.19 -5.54	9.82 -8.52
Wave 3, in	-0.301 2.238	49 0.30	2.50 -2.84	4.17 -4.49	6.30 -6.08	10.27 -8.33
Wave 4, in	-0.354 2.311	50 0.30	2.71 -2.70	4.58 -4.67	6.21 -6.31	10.93 -7.63

TABLE 6.26

MODEL IRREGULAR WAVE TEST RESULTS
 Boom 1 x 24 ft B/W = 34.3
 Waves 1.00 ft Significant Height

Run(s) : 12, Speed 0.42 fps

	Mean/RMS	Osc/Buf	Avg	1/3	1/10	Extreme
Heave 0, in	-1.050 4.302	22 0.30	3.70 -4.80	7.93 -9.00	10.03 -12.31	10.30 -12.47
Heave 2, in	-0.536 3.516	20 0.30	3.72 -3.85	7.63 -7.24	8.70 -8.18	8.95 -8.50
Heave 3, in	0.325 2.972	18 0.30	4.19 -2.86	6.96 -4.85	7.67 -5.97	7.67 -5.97
Heave 4, in	0.449 3.069	25 0.30	3.82 -2.53	7.35 -4.82	8.30 -6.62	8.65 -7.04
Wave 0, in	-0.277 3.190	22 0.30	3.39 -3.61	6.64 -6.06	8.02 -7.44	8.32 -7.73
Wave 2, in	-0.174 3.143	20 0.30	3.65 -3.57	6.97 -6.17	7.75 -7.22	7.80 -7.90
Wave 3, in	-0.174 3.167	19 0.30	3.93 -3.70	6.99 -5.86	7.99 -6.74	7.99 -6.74
Wave 4, in	-0.213 3.059	21 0.30	3.73 -3.05	7.36 -5.58	8.17 -7.20	8.49 -7.21

TABLE 6.27

MODEL BREAKING WAVE TEST RESULTS

Boom 1 x 24 ft B/W = 34.3

Waves 1.4 ft Significant Height

Run(s) : 16, Speed 0.393 fps

	Mean/RMS	Osc/Buff	Avg	1/3	1/10	Extreme
Heave 0, in	-0.170 3.068	114 0.30	2.96 -2.87	6.95 -6.83	9.86 -9.29	12.13 -13.37
Heave 2, in	-0.128 2.512	70 0.30	3.42 -3.81	6.52 -6.30	8.48 -7.58	9.21 -8.73
Heave 3, in	0.265 2.323	73 0.30	3.52 -2.96	6.57 -5.35	8.07 -6.58	9.69 -8.37
Heave 4, in	0.863 2.591	119 0.30	3.24 -1.53	6.52 -4.65	8.34 -6.14	9.33 -8.89
Wave 0, in	-0.280 2.140	108 0.30	2.23 -2.24	5.21 -4.75	7.77 -6.59	9.79 -8.15
Wave 2, in	-0.187 2.174	108 0.30	2.34 -2.23	5.38 -4.66	8.41 -6.49	10.43 -7.83
Wave 3, in	-0.172 2.214	109 0.30	2.43 -2.25	5.53 -4.77	8.18 -6.52	10.50 -7.67
Wave 4, in	-0.261 2.251	108 0.30	2.43 -2.41	5.57 -4.90	8.18 -6.69	9.84 -7.33

TABLE 6.28

MODEL BREAKING WAVE TEST RESULTS
 Boom 1 x 24 ft B/W = 34.3
 Waves 1.4 ft Significant Height

Run(s) : 15, Speed 0.829 fps

	Mean/RMS	Osc/Buff	Avg	1/3	1/10	Extreme
Heave 0, in	0.029 3.420	37 0.30	5.08 -3.95	8.87 -8.93	11.05 -15.06	12.12 -17.69
Heave 2, in	-0.175 2.424	35 0.30	3.51 -3.56	6.42 -6.71	8.00 -8.87	8.04 -10.70
Heave 3, in	0.273 2.118	36 0.30	3.63 -2.65	6.42 -4.97	8.10 -5.97	9.80 -6.36
Heave 4, in	2.225 2.387	41 0.30	4.69 -1.32	7.48 -4.93	8.48 -6.83	8.60 -7.56
Wave 0, in	-0.328 1.877	36 0.30	2.68 -2.79	5.61 -5.04	8.05 -6.43	8.38 -7.21
Wave 2, in	-0.239 1.939	37 0.30	2.80 -2.71	5.86 -5.02	8.09 -6.54	8.28 -6.88
Wave 3, in	-0.247 2.180	35 0.30	3.41 -3.19	6.47 -5.70	8.44 -7.27	9.40 -7.61
Wave 4, in	-0.309 2.166	37 0.30	3.19 -3.16	6.39 -5.70	8.24 -6.89	8.55 -7.42

TABLE 6.29

MODEL IRREGULAR WAVE TEST RESULTS
 Boom 1 x 24 ft B/W = 10.4
 Waves 0.50 ft Significant Height

Run(s) : 27, Speed 0.425 fps

	Mean/RMS	Osc/Buff	Avg	1/3	1/10	Extreme
Heave 0, in	-0.850 1.869	125 0.30	1.28 -2.90	2.82 -4.56	3.93 -5.67	4.59 -6.71
Heave 2, in	-0.097 1.482	121 0.30	1.65 -1.74	3.06 -2.92	3.89 -3.75	5.30 -4.70
Heave 3, in	0.478 1.333	105 0.30	2.15 -1.04	3.31 -1.93	4.05 -2.44	4.87 -3.07
Heave 4, in	1.479 1.555	122 0.30	3.36 -0.31	4.54 -1.56	5.22 -2.37	6.77 -3.75
Wave 0, in	-0.432 1.341	121 0.30	1.20 -1.90	2.46 -2.92	3.21 -3.60	3.97 -4.76
Wave 2, in	-0.306 1.380	121 0.30	1.44 -1.76	2.77 -2.82	3.59 -3.48	4.74 -4.28
Wave 3, in	-0.346 1.374	127 0.30	1.31 -1.77	2.49 -2.90	3.40 -3.46	5.26 -4.15
Wave 4, in	-0.412 1.400	119 0.30	1.40 -1.93	2.56 -3.05	3.35 -3.70	4.32 -4.98

TABLE 6.30

MODEL IRREGULAR WAVE TEST RESULTS

Boom 1 x 24 ft B/W = 10.4

Waves 0.50 ft Significant Height

Run(s) : 28, Speed 0.872 fps

	Mean/RMS	Osc/Buff	Avg	1/3	1/10	Extreme
Heave 0, in	-0.572 2.041	65 0.30	1.78 -2.85	3.30 -4.74	4.41 -6.07	4.76 -6.94
Heave 2, in	-0.154 1.437	59 0.30	1.48 -1.75	2.83 -3.08	3.88 -3.94	4.47 -4.22
Heave 3, in	0.131 1.301	53 0.30	1.76 -1.28	2.99 -2.27	3.97 -2.98	4.57 -3.36
Heave 4, in	2.365 1.241	68 0.30	3.68 0.90	4.83 -0.15	5.61 -0.88	6.29 -1.99
Wave 0, in	-0.498 1.316	65 0.30	1.02 -1.87	2.24 -2.96	3.22 -3.67	3.92 -4.27
Wave 2, in	-0.364 1.375	66 0.30	1.26 -1.77	2.59 -2.79	3.49 -3.64	4.07 -4.17
Wave 3, in	-0.433 1.411	63 0.30	1.22 -2.02	2.59 -3.00	3.50 -3.89	4.23 -4.33
Wave 4, in	-0.519 1.415	66 0.30	1.12 -1.99	2.30 -3.16	3.47 -4.00	4.55 -4.55

TABLE 6.31

MODEL IRREGULAR WAVE TEST RESULTS

Boom 1 x 24 ft B/W = 10.4

Waves 0.75 ft Significant Height

Run(s) : 29, Speed 0.396 fps

	Mean/RMS	Osc/Buff	Avg	1/3	1/10	Extreme
Heave 0, in	-1.281 2.948	115 0.30	1.77 -4.19	4.34 -6.89	6.44 -9.21	12.71 -13.45
Heave 2, in	-0.103 2.552	100 0.30	2.62 -2.73	4.59 -4.99	6.16 -7.68	11.00 -10.48
Heave 3, in	0.091 2.157	95 0.30	2.89 -2.31	4.84 -3.85	6.32 -5.21	10.77 -6.42
Heave 4, in	1.501 2.160	124 0.30	3.96 -0.83	5.92 -2.59	7.42 -3.96	10.45 -5.56
Wave 0, in	-0.441 2.098	104 0.30	2.23 -2.72	4.12 -4.28	5.76 -5.24	11.69 -6.33
Wave 2, in	-0.312 2.121	109 0.30	2.24 -2.55	4.20 -4.13	5.93 -5.28	12.33 -6.46
Wave 3, in	-0.349 2.235	112 0.30	2.36 -2.58	4.31 -4.31	5.74 -5.65	10.58 -7.43
Wave 4, in	-0.432 2.212	109 0.30	2.29 -2.77	4.16 -4.44	5.80 -5.76	10.37 -8.78

TABLE 6.32

MODEL IRREGULAR WAVE TEST RESULTS

Boom 1 x 24 ft B/W = 10.4

Waves 0.75 ft Significant Height

Run(s) : 30, Speed 0.825 fps

	Mean/RMS	Osc/Buff	Avg	1/3	1/10	Extreme
Heave 0, in	-0.800 3.241	58 0.30	2.56 -3.76	4.67 -7.07	6.62 -10.68	9.96 -19.84
Heave 2, in	-0.074 2.419	47 0.30	2.80 -2.98	4.61 -5.05	6.77 -7.46	10.09 -12.02
Heave 3, in	0.091 2.065	43 0.30	2.77 -2.57	4.40 -3.90	6.31 -5.48	10.01 -7.21
Heave 4, in	2.397 1.801	68 0.30	4.15 0.56	5.94 -1.10	7.28 -2.33	10.55 -3.45
Wave 0, in	-0.498 2.275	52 0.30	2.16 -2.86	3.90 -4.78	5.62 -6.18	9.32 -8.35
Wave 2, in	-0.372 2.267	52 0.30	2.28 -2.82	4.01 -4.69	5.88 -6.19	9.68 -7.80
Wave 3, in	-0.452 2.234	53 0.30	2.13 -2.77	4.17 -4.60	5.97 -6.20	9.77 -8.49
Wave 4, in	-0.510 2.332	48 0.30	2.62 -2.95	4.46 -4.69	6.68 -6.79	11.53 -7.97

TABLE 6.33

MODEL BREAKING WAVE TEST RESULTS

Boom 1 x 24 ft B/W = 10.4

Waves 1.4 ft Significant Height

Run(s) : 31, Speed 0.418 fps

	Mean/RMS	Osc/Buf	Avg	1/3	1/10	Extreme
Heave 0, in	-1.400 3.547	97 0.30	3.06 -5.71	6.69 -8.88	8.74 -11.09	9.73 -12.62
Heave 2, in	-0.572 2.766	93 0.30	3.13 -3.97	5.71 -6.23	7.30 -7.28	8.56 -7.74
Heave 3, in	-0.220 2.519	98 0.30	3.13 -3.09	5.41 -5.30	6.81 -6.67	7.99 -7.46
Heave 4, in	1.120 2.695	104 0.30	4.71 -2.25	7.09 -4.43	8.05 -5.48	8.52 -6.92
Wave 0, in	-0.478 2.545	91 0.30	3.34 -3.62	5.85 -5.49	7.72 -6.86	9.66 -7.79
Wave 2, in	-0.361 2.567	92 0.30	3.48 -3.50	6.14 -5.50	8.37 -7.06	9.94 -7.85
Wave 3, in	-0.415 2.655	94 0.30	3.50 -3.58	6.14 -5.73	7.74 -7.34	8.82 -7.95
Wave 4, in	-0.495 2.688	95 0.30	3.39 -3.68	6.24 -5.89	8.10 -7.28	10.25 -8.61

TABLE 6.34

MODEL BREAKING WAVE TEST RESULTS

Boom 1 x 24 ft B/W = 10.4

Waves 1.4 ft Significant Height

Run(s) : 32, Speed 0.824 fps

	Mean/RMS	Osc/Buf	Avg	1/3	1/10	Extreme
Heave 0, in	-0.990 3.823	54 0.30	2.95 -4.55	7.06 -9.18	10.16 -12.75	10.79 -15.70
Heave 2, in	-0.123 2.686	40 0.30	3.65 -3.85	6.39 -7.08	7.30 -9.63	7.69 -13.12
Heave 3, in	0.274 2.163	44 0.30	3.41 -2.18	6.56 -4.04	7.60 -5.05	8.41 -5.77
Heave 4, in	2.263 2.092	61 0.30	4.35 -0.04	6.84 -2.58	8.16 -4.05	8.96 -4.44
Wave 0, in	-0.487 2.048	47 0.30	2.00 -2.65	4.68 -5.03	6.98 -6.74	8.12 -7.25
Wave 2, in	-0.375 2.113	47 0.30	2.46 -2.74	5.37 -5.17	7.68 -6.92	8.22 -7.58
Wave 3, in	-0.440 2.447	49 0.30	2.78 -3.16	6.00 -5.77	8.07 -7.14	9.12 -7.34
Wave 4, in	-0.509 2.361	54 0.30	2.39 -2.82	5.53 -5.49	8.16 -6.98	8.66 -7.59

TABLE 6.35

MODEL IRREGULAR WAVE TEST RESULTS

Boom 1 x 24 ft B/W = 4.4

Waves 0.50 ft Significant Height

Run(s) : 41, Speed 0.436 fps

	Mean/RMS	Osc/Buff	Avg	1/3	1/10	Extreme
Heave 0, in	-1.397 2.041	123 0.30	0.88 -3.57	2.67 -5.51	3.86 -6.70	5.86 -8.05
Heave 2, in	1.046 1.522	115 0.30	2.73 -0.70	4.11 -1.94	5.01 -2.44	6.33 -3.30
Heave 3, in	0.372 1.358	101 0.30	2.04 -1.10	3.23 -2.08	3.99 -2.57	5.29 -3.53
Heave 4, in	0.819 1.558	117 0.30	2.70 -1.04	3.90 -2.31	4.83 -3.19	5.72 -4.43
Wave 0, in	-0.288 1.362	125 0.30	1.34 -1.70	2.59 -2.80	3.51 -3.30	5.74 -3.64
Wave 2, in	-0.160 1.402	126 0.30	1.55 -1.63	2.79 -2.77	3.73 -3.41	5.26 -4.28
Wave 3, in	-0.216 1.420	130 0.30	1.49 -1.64	2.76 -2.79	3.50 -3.44	4.09 -4.71
Wave 4, in	-0.391 1.467	123 0.30	1.40 -1.96	2.68 -3.15	3.34 -3.85	4.92 -4.94

TABLE 6.36

MODEL IRREGULAR WAVE TEST RESULTS
 Boom 1 x 24 ft B/W = 4.4
 Waves 0.50 ft Significant Height

Run(s) : 42, Speed 0.856 fps

	Mean/RMS	Osc/Buff	Avg	1/3	1/10	Extreme
Heave 0, in	-1.518 2.030	65 0.30	0.76 -3.65	2.24 -5.63	3.50 -7.54	4.07 -8.88
Heave 2, in	1.230 1.510	59 0.30	2.98 -0.57	4.30 -1.84	5.15 -2.66	5.91 -3.33
Heave 3, in	0.773 1.274	55 0.30	2.38 -0.60	3.57 -1.61	4.49 -2.45	4.83 -2.85
Heave 4, in	1.529 1.229	66 0.30	2.93 0.09	4.02 -0.90	4.85 -1.66	5.80 -2.74
Wave 0, in	-0.314 1.302	67 0.30	1.20 -1.68	2.30 -2.84	3.36 -3.44	4.60 -3.61
Wave 2, in	-0.192 1.371	66 0.30	1.41 -1.65	2.69 -2.67	3.67 -3.48	5.07 -4.16
Wave 3, in	-0.272 1.442	69 0.30	1.45 -1.71	2.75 -2.82	3.72 -3.80	4.49 -4.37
Wave 4, in	-0.436 1.463	67 0.30	1.28 -1.95	2.48 -3.19	3.35 -4.00	3.77 -4.89

TABLE 6.37

MODEL IRREGULAR WAVE TEST RESULTS
 Boom 1 x 24 ft B/W = 4.4
 Waves 0.75 ft Significant Height

Run(s) : 43, Speed 0.392 fps

	Mean/RMS	Osc/Buf	Avg	1/3	1/10	Extreme
Heave 0, in	-2.445 3.430	117 0.30	0.98 -5.51	3.68 -8.88	5.65 -11.78	10.13 -15.63
Heave 2, in	0.966 2.321	105 0.30	3.52 -1.68	5.54 -3.38	6.90 -4.84	11.60 -6.79
Heave 3, in	0.579 2.186	96 0.30	3.34 -1.87	5.21 -3.41	6.80 -4.74	11.33 -5.96
Heave 4, in	0.872 2.289	121 0.30	3.38 -1.66	5.56 -3.53	6.90 -5.21	10.86 -7.14
Wave 0, in	-0.302 2.114	109 0.30	2.31 -2.49	4.27 -4.03	6.05 -5.03	12.50 -6.84
Wave 2, in	-0.180 2.120	110 0.30	2.40 -2.47	4.35 -3.99	5.91 -5.05	12.53 -6.30
Wave 3, in	-0.218 2.222	110 0.30	2.49 -2.51	4.44 -4.21	5.96 -5.51	11.82 -6.64
Wave 4, in	-0.374 2.232	111 0.30	2.38 -2.62	4.23 -4.37	5.60 -5.84	9.94 -8.62

TABLE 6.38

MODEL IRREGULAR WAVE TEST RESULTS

Boom 1 x 24 ft B/W = 4.4

Waves 0.75 ft Significant Height

Run(s) : 44, Speed 0.839 fps

	Mean/RMS	Osc/Buff	Avg	1/3	1/10	Extreme
Heave 0, in	-2.488 3.698	55 0.30	1.46 -5.85	3.65 -10.10	5.85 -15.05	8.45 -20.29
Heave 2, in	1.132 2.515	47 0.30	4.02 -1.83	5.92 -4.06	7.89 -7.04	10.19 -12.78
Heave 3, in	0.954 2.128	45 0.30	3.65 -1.50	5.32 -2.98	7.43 -4.71	10.66 -6.99
Heave 4, in	1.698 1.934	56 0.30	3.90 -0.49	5.62 -1.91	7.15 -3.07	10.72 -5.01
Wave 0, in	-0.363 2.210	47 0.30	2.32 -2.81	4.08 -4.45	6.17 -5.91	8.89 -7.60
Wave 2, in	-0.241 2.221	48 0.30	2.42 -2.80	4.18 -4.40	6.49 -5.87	9.40 -7.23
Wave 3, in	-0.324 2.256	50 0.30	2.46 -2.61	4.51 -4.55	6.42 -6.01	10.36 -8.38
Wave 4, in	-0.485 2.334	51 0.30	2.39 -2.90	4.33 -4.67	6.20 -6.36	11.46 -7.65

TABLE 6.39

MODEL BREAKING WAVE TEST RESULTS

Boom 1 x 24 ft B/W = 4.4

Waves 1.4 ft Significant Height

Run(s) : 45, Speed 0.398 fps

	Mean/RMS	Osc/Buf	Avg	1/3	1/10	Extreme
Heave 0, in	-3.044 4.350	100 0.30	2.37 -8.04	5.50 -12.34	7.56 -14.94	9.45 -16.39
Heave 2, in	0.995 2.848	100 0.30	4.84 -2.63	7.20 -4.80	8.71 -6.11	9.66 -7.41
Heave 3, in	0.621 2.606	105 0.30	4.07 -2.46	6.49 -4.37	7.63 -5.62	8.40 -5.97
Heave 4, in	0.422 2.843	108 0.30	4.31 -3.20	6.61 -5.47	7.34 -6.90	8.07 -10.23
Wave 0, in	-0.248 2.601	100 0.30	3.55 -3.43	6.04 -5.23	7.87 -6.39	9.69 -7.58
Wave 2, in	-0.127 2.611	99 0.30	3.76 -3.31	6.35 -5.18	8.41 -6.57	10.01 -7.55
Wave 3, in	-0.172 2.735	101 0.30	3.78 -3.46	6.53 -5.58	8.15 -7.01	9.82 -7.64
Wave 4, in	-0.328 2.763	100 0.30	3.70 -3.68	6.52 -5.71	8.35 -7.11	10.32 -8.00

TABLE 6.40

MODEL BREAKING WAVE TEST RESULTS

Boom 1 x 24 ft B/W = 4.4

Waves 1.4 ft Significant Height

Run(s) : 46, Speed 0.841 fps

	Mean/RMS	Osc/Buf	Avg	1/3	1/10	Extreme
Heave 0, in	-2.831 4.514	49 0.30	2.21 -7.33	6.44 -13.57	9.26 -19.36	9.87 -20.29
Heave 2, in	0.983 2.867	42 0.30	4.89 -2.72	7.69 -6.15	9.03 -9.34	9.68 -11.47
Heave 3, in	1.138 2.218	51 0.30	3.86 -1.34	6.83 -3.45	8.35 -4.62	9.28 -5.44
Heave 4, in	1.513 2.148	62 0.30	3.74 -0.87	6.23 -3.58	7.40 -5.19	7.98 -6.25
Wave 0, in	-0.300 1.970	48 0.30	2.33 -2.42	4.88 -4.56	7.54 -5.92	8.83 -6.76
Wave 2, in	-0.166 2.081	48 0.30	2.64 -2.45	5.33 -4.66	8.04 -5.92	9.69 -6.72
Wave 3, in	-0.202 2.486	51 0.30	3.02 -2.90	6.25 -5.31	8.42 -6.54	9.75 -7.40
Wave 4, in	-0.403 2.355	56 0.30	2.54 -2.63	5.69 -5.18	8.59 -6.64	9.23 -8.08

TABLE 6.41

MODEL IRREGULAR WAVE TEST RESULTS

Boom 1 x 12 ft B/W = 9.9

Waves 0.50 ft Significant Height

Run(s) : 157, Speed 0.433 fps

	Mean/RMS	Osc/Buf	Avg	1/3	1/10	Extreme
Heave 0, in	0.760 1.637	119 0.30	2.72 -1.09	4.22 -2.53	5.05 -3.56	6.25 -4.74
Heave 2, in						
Heave 3, in						
Heave 4, in	2.190 1.517	137 0.30	3.79 0.58	5.17 -0.79	6.26 -1.93	7.95 -4.12
Wave 0, in	-0.326 1.351	121 0.30	1.33 -1.76	2.47 -2.97	3.20 -3.67	4.28 -4.56
Wave 2, in	-0.197 1.379	117 0.30	1.49 -1.74	2.68 -2.90	3.54 -3.61	4.96 -4.37
Wave 3, in	-0.131 1.435	119 0.30	1.65 -1.66	2.91 -2.88	3.67 -3.68	5.11 -4.81
Wave 4, in	-0.271 1.396	125 0.30	1.42 -1.72	2.69 -2.92	3.43 -3.69	4.13 -4.43

TABLE 6.42

MODEL IRREGULAR WAVE TEST RESULTS

Boom 1 x 12 ft B/W = 9.9

Waves 0.50 ft Significant Height

Run(s) : 158, Speed 0.829 fps

	Mean/RMS	Osc/Buff	Avg	1/3	1/10	Extreme
Heave 0, in	0.600 1.716	74 0.30	2.38 -1.33	3.83 -2.74	4.97 -3.74	5.79 -4.70
Heave 2, in						
Heave 3, in						
Heave 4, in	3.147 1.592	76 0.30	4.75 1.41	5.94 -0.34	6.94 -2.10	7.52 -3.49
Wave 0, in	-0.387 1.290	68 0.30	1.08 -1.72	2.29 -2.78	3.31 -3.44	4.01 -3.87
Wave 2, in	-0.248 1.325	68 0.30	1.28 -1.61	2.50 -2.69	3.49 -3.41	4.70 -3.66
Wave 3, in	-0.208 1.388	65 0.30	1.48 -1.72	2.76 -2.84	3.75 -3.58	4.92 -3.79
Wave 4, in	-0.366 1.406	71 0.30	1.21 -1.81	2.51 -2.96	3.42 -3.75	4.84 -4.25

TABLE 6.43

MODEL IRREGULAR WAVE TEST RESULTS

Boom 1 x 12 ft B/W = 9.9

Waves 0.75 ft Significant Height

Run(s) : 159, Speed 0.421 fps

	Mean/RMS	Osc/Buf	Avg	1/3	1/10	Extreme
Heave 0, in	0.278 2.689	102 0.30	3.21 -2.36	5.71 -4.40	7.63 -6.76	12.83 -10.13
Heave 2, in						
Heave 3, in						
Heave 4, in	1.965 2.269	138 0.30	4.22 0.00	6.47 -2.30	8.16 -3.45	11.16 -5.01
Wave 0, in	-0.331 2.061	95 0.30	2.41 -2.54	4.14 -4.00	5.85 -5.10	10.85 -6.47
Wave 2, in	-0.202 2.092	97 0.30	2.53 -2.36	4.37 -3.84	6.44 -4.96	12.57 -6.43
Wave 3, in	-0.140 2.167	103 0.30	2.53 -2.30	4.52 -3.87	6.28 -4.95	13.10 -6.51
Wave 4, in	-0.280 2.108	103 0.30	2.29 -2.49	4.27 -4.04	5.92 -5.09	12.44 -5.88

TABLE 6.44

MODEL IRREGULAR WAVE TEST RESULTS

Boom 1 x 12 ft B/W = 9.9

Waves 0.75 ft Significant Height

Run(s) : 160, Speed 0.850 fps

	Mean/RMS	Osc/Buf	Avg	1/3	1/10	Extreme
Heave 0, in	0.565	56	3.49	5.77	7.75	10.72
	2.620	0.30	-2.09	-4.66	-6.65	-8.34
Heave 2, in						
Heave 3, in						
Heave 4, in	2.770	64	5.05	7.05	8.35	8.87
	2.402	0.30	0.41	-1.96	-3.58	-4.93
Wave 0, in	-0.402	47	2.31	4.14	6.23	9.11
	2.186	0.30	-2.90	-4.51	-6.12	-7.05
Wave 2, in	-0.252	47	2.51	4.38	6.54	9.23
	2.251	0.30	-2.90	-4.53	-6.09	-7.00
Wave 3, in	-0.207	50	2.57	4.53	6.43	9.81
	2.337	0.30	-2.77	-4.59	-5.71	-7.23
Wave 4, in	-0.361	56	2.15	4.13	6.42	10.17
	2.255	0.30	-2.61	-4.62	-6.33	-8.55

TABLE 6.45

MODEL IRREGULAR WAVE TEST RESULTS
 Boom 1 x 12 ft B/W = 9.9
 Waves 1.00 ft Significant Height

Run(s) : 161, Speed 0.417 fps

	Mean/RMS	Osc/Buff	Avg	1/3	1/10	Extreme
Heave 0, in	-0.305 3.615	94 0.30	3.80 -3.67	6.84 -7.07	8.93 -9.57	11.89 -14.87
Heave 2, in						
Heave 3, in						
Heave 4, in	1.826 3.294	112 0.30	5.12 -1.16	8.12 -4.18	10.02 -5.79	13.43 -8.30
Wave 0, in	-0.393 3.064	92 0.30	3.40 -3.34	6.13 -5.91	7.81 -7.44	9.39 -9.07
Wave 2, in	-0.264 3.105	90 0.30	3.70 -3.36	6.35 -5.88	8.05 -7.29	9.00 -8.94
Wave 3, in	-0.195 3.239	92 0.30	3.86 -3.42	6.59 -6.05	8.01 -7.53	8.93 -9.83
Wave 4, in	-0.329 3.143	91 0.30	3.63 -3.43	6.38 -5.81	8.05 -7.51	8.64 -10.02

TABLE 6.46

MODEL BREAKING WAVE TEST RESULTS

Boom 1 x 12 ft B/W = 9.9

Waves 1.4 ft Significant Height

Run(s) : 162, Speed 0.425 fps

	Mean/RMS	Osc/Buf	Avg	1/3	1/10	Extreme
Heave 0, in	0.163 3.610	100 0.30	4.64 -4.03	9.17 -6.28	11.78 -7.31	12.69 -8.90
Heave 2, in						
Heave 3, in						
Heave 4, in	2.212 2.906	135 0.30	5.43 -0.19	8.53 -3.63	10.18 -5.54	12.93 -7.66
Wave 0, in	-0.343 2.559	98 0.30	3.36 -3.35	5.93 -5.26	7.88 -6.48	9.50 -7.15
Wave 2, in	-0.217 2.617	98 0.30	3.60 -3.24	6.40 -5.26	8.51 -6.48	10.34 -7.51
Wave 3, in	-0.149 2.734	101 0.30	3.73 -3.14	6.63 -5.42	8.39 -6.62	10.27 -7.48
Wave 4, in	-0.280 2.737	102 0.30	3.54 -3.44	6.38 -5.59	8.18 -6.75	10.14 -7.23

TABLE 6.47

MODEL BREAKING WAVE TEST RESULTS
 Boom 1 x 12 ft B/W = 9.9
 Waves 1.4 ft Significant Height

Run(s) : 163, Speed 0.847 fps

	Mean/RMS	Osc/Buf	Avg	1/3	1/10	Extreme
Heave 0, in	0.429 3.553	45 0.30	5.25 -3.78	9.80 -7.14	12.96 -9.75	14.04 -13.74
Heave 2, in						
Heave 3, in						
Heave 4, in	3.273 2.153	75 0.30	5.36 1.53	7.68 -1.75	8.79 -4.08	9.36 -5.16
Wave 0, in	-0.364 1.957	46 0.30	2.43 -2.47	5.23 -4.55	7.44 -5.73	8.02 -6.04
Wave 2, in	-0.234 2.016	47 0.30	2.59 -2.41	5.47 -4.51	7.69 -5.71	8.59 -6.09
Wave 3, in	-0.179 2.245	47 0.30	3.01 -2.60	6.09 -4.95	8.32 -6.13	8.90 -6.91
Wave 4, in	-0.296 2.516	49 0.30	3.16 -3.04	6.27 -5.43	8.76 -6.68	9.44 -7.63

TABLE 6.48

MODEL IRREGULAR WAVE TEST RESULTS

Boom 1.5 x 24 ft B/W = 33.6

Waves 0.50 ft Significant Height

Run(s) : 108, Speed 0.562 fps

	Mean/RMS	Osc/Buff	Avg	1/3	1/10	Extreme
Heave 0, in	-0.779 1.849	83 0.30	1.34 -3.03	2.56 -4.76	3.34 -5.94	4.26 -7.01
Heave 2, in	2.167 1.405	86 0.30	3.76 0.62	4.92 -0.68	5.69 -1.57	6.68 -2.60
Heave 3, in	2.835 1.394	79 0.30	4.49 1.14	5.75 0.10	6.67 -0.62	7.95 -1.59
Heave 4, in	2.748 1.577	96 0.30	4.42 1.04	5.65 -0.31	6.71 -0.85	7.00 -1.35
Wave 0, in	-0.237 1.350	92 0.30	1.34 -1.75	2.35 -2.83	2.92 -3.47	4.44 -3.81
Wave 2, in	-0.182 1.369	92 0.30	1.49 -1.70	2.59 -2.81	3.21 -3.50	4.20 -4.12
Wave 3, in	-0.211 1.402	90 0.30	1.62 -1.75	2.89 -2.71	3.81 -3.48	4.43 -4.38
Wave 4, in	-0.365 1.502	89 0.30	1.50 -2.13	2.75 -3.33	3.56 -4.03	4.34 -5.32

TABLE 6.49

MODEL IRREGULAR WAVE TEST RESULTS

Boom 1.5 x 24 ft B/W = 33.6

Waves 0.50 ft Significant Height

Run(s) : 109, Speed 1.023 fps

	Mean/RMS	Osc/Buff	Avg	1/3	1/10	Extreme
Heave 0, in	-1.018 1.794	52 0.30	0.92 -3.00	2.30 -4.59	3.02 -5.82	3.39 -6.67
Heave 2, in	1.694 1.421	49 0.30	3.27 0.16	4.43 -1.05	5.35 -2.07	5.87 -2.53
Heave 3, in	2.633 1.194	47 0.30	4.02 1.21	5.04 0.16	5.72 -0.53	5.97 -0.67
Heave 4, in	4.267 1.306	62 0.30	5.33 2.96	6.21 1.48	6.66 0.67	7.35 -1.66
Wave 0, in	-0.282 1.194	54 0.30	1.08 -1.58	2.18 -2.44	2.91 -3.21	3.33 -4.20
Wave 2, in	-0.228 1.233	57 0.30	1.22 -1.59	2.29 -2.50	3.18 -3.30	3.54 -3.92
Wave 3, in	-0.261 1.301	56 0.30	1.31 -1.65	2.37 -2.68	3.09 -3.58	4.11 -4.22
Wave 4, in	-0.385 1.341	56 0.30	1.18 -1.85	2.38 -2.84	3.56 -3.65	4.61 -3.94

TABLE 6.50

MODEL IRREGULAR WAVE TEST RESULTS

Boom 1.5 x 24 ft B/W = 33.6

Waves 0.75 ft Significant Height

Run(s) : 110, Speed 0.490 fps

	Mean/RMS	Osc/Buff	Avg	1/3	1/10	Extreme
Heave 0, in	-1.223 2.933	84 0.30	2.08 -4.34	4.40 -7.03	6.43 -9.63	12.38 -13.13
Heave 2, in	1.872 2.594	81 0.30	4.68 -0.69	6.82 -3.23	8.49 -5.62	11.73 -8.62
Heave 3, in	2.380 2.485	80 0.30	5.00 -0.21	7.32 -2.50	8.91 -4.52	11.57 -7.25
Heave 4, in	2.135 2.469	114 0.30	4.52 0.05	6.88 -2.07	9.13 -3.29	13.38 -4.34
Wave 0, in	-0.243 2.253	80 0.30	2.57 -2.70	4.44 -4.55	6.35 -6.29	8.86 -8.98
Wave 2, in	-0.183 2.325	84 0.30	2.54 -2.58	4.69 -4.46	6.69 -6.57	9.88 -9.03
Wave 3, in	-0.221 2.370	88 0.30	2.54 -2.51	4.63 -4.50	6.54 -6.57	8.51 -9.25
Wave 4, in	-0.398 2.367	92 0.30	2.22 -2.79	4.34 -4.72	6.06 -6.08	9.34 -8.91

TABLE 6.51

MODEL IRREGULAR WAVE TEST RESULTS
 Boom 1.5 x 24 ft B/W = 33.6
 Waves 0.75 ft Significant Height

Run(s) : 111, Speed 1.049 fps

	Mean/RMS	Osc/Buff	Avg	1/3	1/10	Extreme
Heave 0, in	-0.650 2.854	43 0.30	2.70 -3.53	5.05 -6.32	7.13 -8.28	7.49 -10.22
Heave 2, in	1.828 2.513	36 0.30	4.88 -1.16	6.82 -3.05	8.94 -4.72	10.89 -5.64
Heave 3, in	2.530 2.204	36 0.30	5.21 -0.21	6.83 -2.00	8.74 -4.52	11.43 -5.62
Heave 4, in	2.828 2.612	58 0.30	5.04 0.66	7.17 -1.96	8.39 -3.69	12.06 -5.41
Wave 0, in	-0.278 2.316	37 0.30	2.69 -3.00	4.67 -4.64	6.40 -6.29	8.99 -7.82
Wave 2, in	-0.229 2.301	38 0.30	2.66 -2.85	4.63 -4.64	6.44 -6.26	9.53 -7.60
Wave 3, in	-0.290 2.354	40 0.30	2.61 -2.62	4.64 -4.54	6.25 -6.54	10.56 -8.68
Wave 4, in	-0.454 2.430	40 0.30	2.62 -2.97	4.68 -4.71	6.80 -6.60	11.35 -7.81

TABLE 6.52

MODEL IRREGULAR WAVE TEST RESULTS

Boom 1.5 x 24 ft B/W = 33.6

Waves 1.00 ft Significant Height

Run(s) : 112, Speed 0.509 fps

	Mean/RMS	Osc/Buff	Avg	1/3	1/10	Extreme
Heave 0, in	-1.015 3.869	76 0.30	3.56 -4.74	6.45 -8.24	8.69 -10.30	10.60 -11.70
Heave 2, in	2.047 3.363	71 0.30	6.13 -1.43	8.80 -4.28	10.46 -5.79	11.43 -6.98
Heave 3, in	2.167 3.026	72 0.30	5.69 -0.95	7.98 -3.81	9.26 -5.41	10.74 -6.71
Heave 4, in	1.674 3.390	100 0.30	4.97 -1.28	7.66 -4.89	10.03 -6.81	14.07 -8.22
Wave 0, in	-0.264 3.204	74 0.30	3.85 -3.49	6.71 -6.04	8.80 -7.05	11.19 -7.41
Wave 2, in	-0.218 3.187	75 0.30	3.72 -3.41	6.59 -5.91	8.47 -7.07	9.72 -7.79
Wave 3, in	-0.241 3.259	77 0.30	3.60 -3.34	6.61 -6.00	8.67 -7.37	13.26 -8.29
Wave 4, in	-0.413 3.209	76 0.30	3.46 -3.63	6.51 -6.14	8.99 -7.64	13.46 -8.66

TABLE 6.53

MODEL BREAKING WAVE TEST RESULTS

Boom 1.5 x 24 ft B/W = 33.6
 Waves 1.4 ft Significant Height

Run(s) : 113, Speed 0.546 fps

	Mean/RMS	Osc/Buf	Avg	1/3	1/10	Extreme
Heave 0, in	-0.403 3.565	73 0.30	4.43 -4.46	7.86 -7.84	10.43 -9.97	12.21 -12.77
Heave 2, in	1.504 2.842	68 0.30	5.29 -1.80	8.14 -4.39	9.84 -6.22	12.03 -9.24
Heave 3, in	2.172 2.694	74 0.30	5.50 -0.67	8.29 -3.45	9.79 -6.01	10.46 -10.58
Heave 4, in	1.096 3.342	87 0.30	4.68 -2.01	7.74 -5.27	9.25 -7.85	9.81 -11.42
Wave 0, in	-0.255 2.544	70 0.30	3.49 -3.38	6.19 -5.44	7.82 -7.02	9.67 -7.58
Wave 2, in	-0.213 2.568	70 0.30	3.56 -3.31	6.43 -5.49	8.22 -7.09	10.44 -7.66
Wave 3, in	-0.234 2.627	72 0.30	3.65 -3.32	6.54 -5.48	8.12 -6.71	9.60 -7.73
Wave 4, in	-0.408 2.677	74 0.30	3.37 -3.54	6.52 -5.93	8.77 -6.90	9.74 -7.51

TABLE 6.54

MODEL BREAKING WAVE TEST RESULTS

Boom 1.5 x 24 ft B/W = 33.6

Waves 1.4 ft Significant Height

Run(s) : 115, Speed 1.079 fps

	Mean/RMS	Osc/Buff	Avg	1/3	1/10	Extreme
Heave 0, in	-1.175 2.767	26 0.30	3.02 -4.80	7.19 -8.46	9.96 -10.89	10.54 -11.46
Heave 2, in	1.675 2.141	24 0.30	4.95 -1.54	8.15 -4.18	9.73 -7.28	9.96 -7.34
Heave 3, in	2.117 1.858	32 0.30	4.75 0.32	7.84 -1.85	9.53 -3.65	10.03 -5.83
Heave 4, in	3.455 2.152	33 0.30	5.20 1.04	7.30 -2.28	8.79 -4.89	9.25 -7.42
Wave 0, in	-0.273 1.591	26 0.30	2.34 -2.30	5.03 -4.53	7.34 -6.24	7.34 -6.50
Wave 2, in	-0.196 1.851	24 0.30	3.14 -2.82	5.69 -5.09	7.30 -6.45	7.38 -6.54
Wave 3, in	-0.221 2.220	25 0.30	3.55 -3.32	6.72 -5.99	8.98 -7.38	9.90 -7.60
Wave 4, in	-0.400 1.922	27 0.30	2.85 -2.96	5.50 -4.84	7.30 -6.70	7.45 -6.96

TABLE 6.55

MODEL IRREGULAR WAVE TEST RESULTS
 Boom 1.5 x 24 ft B/W = 10.3
 Waves 0.50 ft Significant Height

Run(s) : 124, Speed 0.504 fps

	Mean/RMS	Osc/Buf	Avg	1/3	1/10	Extreme
Heave 0, in	-2.547 1.777	96 0.30	-0.63 -4.51	0.59 -6.29	1.30 -7.55	2.00 -9.40
Heave 2, in	0.443 1.645	93 0.30	1.98 -1.07	3.30 -2.73	4.14 -4.11	5.16 -4.98
Heave 3, in	-0.753 1.592	87 0.30	0.94 -2.29	2.10 -3.95	3.01 -4.93	3.59 -6.44
Heave 4, in	1.741 1.540	103 0.30	3.57 -0.09	4.79 -1.24	5.57 -1.93	6.38 -2.79
Wave 0, in	-0.202 1.326	100 0.30	1.40 -1.67	2.53 -2.69	3.29 -3.24	5.02 -4.25
Wave 2, in	-0.101 1.332	105 0.30	1.51 -1.51	2.72 -2.54	3.54 -3.22	4.92 -3.75
Wave 3, in	-0.120 1.385	102 0.30	1.61 -1.66	2.87 -2.69	3.62 -3.43	4.34 -4.15
Wave 4, in	-0.232 1.464	102 0.30	1.62 -1.86	2.99 -2.96	3.86 -3.75	4.53 -4.97

TABLE 6.56

MODEL IRREGULAR WAVE TEST RESULTS
 Boom 1.5 x 24 ft B/W = 10.3
 Waves 0.50 ft Significant Height

Run(s) : 125, Speed 1.022 fps

	Mean/RMS	Osc/Buf	Avg	1/3	1/10	Extreme
Heave 0, in	-2.345 1.774	51 0.30	-0.37 -4.48	0.92 -5.96	1.93 -7.16	2.62 -8.22
Heave 2, in	0.242 1.398	46 0.30	1.74 -1.25	3.13 -2.42	4.14 -3.27	4.47 -3.63
Heave 3, in	-0.744 1.305	46 0.30	0.67 -2.20	1.89 -3.34	2.82 -4.19	3.46 -5.00
Heave 4, in	3.485 1.118	65 0.30	4.59 2.27	5.24 1.13	5.85 0.06	6.95 -2.39
Wave 0, in	-0.282 1.214	56 0.30	1.14 -1.62	2.17 -2.54	2.87 -3.30	3.34 -3.77
Wave 2, in	-0.173 1.254	59 0.30	1.34 -1.49	2.29 -2.57	3.06 -3.46	3.50 -3.80
Wave 3, in	-0.244 1.325	61 0.30	1.28 -1.64	2.30 -2.76	3.14 -3.55	4.01 -4.36
Wave 4, in	-0.305 1.381	59 0.30	1.32 -1.73	2.47 -2.90	3.53 -3.72	4.34 -4.07

TABLE 6.57

MODEL IRREGULAR WAVE TEST RESULTS
 Boom 1.5 x 24 ft B/W = 10.3
 Waves 0.75 ft Significant Height

Run(s) : 126, Speed 0.503 fps

	Mean/RMS	Osc/Buf	Avg	1/3	1/10	Extreme
Heave 0, in	-2.884 2.925	82 0.30	0.26 -6.08	2.56 -8.87	4.76 -11.13	8.86 -14.02
Heave 2, in	0.614 2.327	76 0.30	3.26 -2.04	5.22 -3.99	7.44 -5.83	9.02 -8.65
Heave 3, in	-0.572 2.448	83 0.30	1.92 -3.08	4.41 -5.11	6.85 -6.23	9.13 -8.36
Heave 4, in	1.564 2.278	109 0.30	3.82 -0.53	6.12 -2.45	8.51 -3.78	11.36 -5.15
Wave 0, in	-0.247 2.315	79 0.30	2.57 -2.64	4.54 -4.50	6.42 -6.41	8.25 -8.53
Wave 2, in	-0.157 2.338	80 0.30	2.70 -2.66	4.74 -4.52	6.30 -6.15	8.69 -8.61
Wave 3, in	-0.205 2.408	87 0.30	2.53 -2.55	4.69 -4.61	6.76 -6.24	9.66 -8.68
Wave 4, in	-0.317 2.415	88 0.30	2.55 -2.72	4.82 -4.58	7.27 -6.09	10.42 -8.60

TABLE 6.58

MODEL IRREGULAR WAVE TEST RESULTS

Boom 1.5 x 24 ft B/W = 10.3

Waves 0.75 ft Significant Height

Run(s) : 127, Speed 1.020 fps

	Mean/RMS	Osc/Buf	Avg	1/3	1/10	Extreme
Heave 0, in	-2.367 2.780	43 0.30	0.52 -5.52	2.98 -8.11	5.05 -10.38	6.90 -11.82
Heave 2, in	0.844 2.319	38 0.30	3.70 -1.76	5.60 -3.56	7.55 -6.03	9.56 -7.86
Heave 3, in	-0.120 2.219	42 0.30	2.52 -2.34	4.37 -4.31	5.92 -6.33	8.91 -7.45
Heave 4, in	3.434 2.068	58 0.30	5.33 1.55	6.73 -0.73	8.16 -2.41	12.85 -3.01
Wave 0, in	-0.314 2.206	39 0.30	2.50 -2.66	4.23 -4.23	6.18 -5.73	8.90 -7.10
Wave 2, in	-0.223 2.196	40 0.30	2.43 -2.52	4.35 -4.15	6.01 -5.79	9.82 -7.82
Wave 3, in	-0.318 2.244	39 0.30	2.77 -2.69	4.58 -4.29	6.93 -6.58	10.27 -8.05
Wave 4, in	-0.349 2.414	45 0.30	2.32 -2.84	4.33 -4.49	6.51 -6.13	11.30 -7.79

TABLE 6.59

MODEL IRREGULAR WAVE TEST RESULTS
 Boom 1.5 x 24 ft B/W = 10.3
 Waves 1.00 ft Significant Height

Run(s) : 128, Speed 0.502 fps

	Mean/RMS	Osc/Buf	Avg	1/3	1/10	Extreme
Heave 0, in	-3.042 3.880	78 0.30	1.26 -6.86	4.25 -10.59	5.86 -12.42	7.37 -13.28
Heave 2, in	0.557 3.263	72 0.30	4.38 -2.81	6.87 -5.77	8.20 -7.21	9.11 -8.28
Heave 3, in	-0.327 3.130	73 0.30	3.35 -3.53	5.69 -6.34	6.89 -8.03	7.17 -9.73
Heave 4, in	1.672 3.104	103 0.30	4.62 -1.24	7.33 -4.05	9.75 -5.60	12.67 -8.43
Wave 0, in	-0.249 3.132	74 0.30	3.69 -3.43	6.39 -5.89	8.15 -7.26	10.09 -7.90
Wave 2, in	-0.144 3.142	75 0.30	3.67 -3.30	6.48 -5.74	8.53 -7.16	12.38 -7.86
Wave 3, in	-0.170 3.269	78 0.30	3.80 -3.34	6.60 -5.92	8.42 -7.25	12.62 -8.82
Wave 4, in	-0.285 3.204	77 0.30	3.60 -3.55	6.71 -5.93	9.00 -7.39	12.88 -7.95

TABLE 6.60

MODEL BREAKING WAVE TEST RESULTS

Boom 1.5 x 24 ft B/W = 10.3

Waves 1.4 ft Significant Height

Run(s) : 129, Speed 0.516 fps

	Mean/RMS	Osc/Buf	Avg	1/3	1/10	Extreme
Heave 0, in	-2.792 3.397	76 0.30	1.34 -6.74	5.33 -9.69	7.76 -11.82	10.49 -12.92
Heave 2, in	0.348 2.578	73 0.30	3.73 -2.77	6.57 -4.95	8.05 -6.42	9.31 -8.38
Heave 3, in	-0.777 2.454	81 0.30	2.18 -3.53	5.09 -5.63	6.87 -7.04	9.11 -8.09
Heave 4, in	1.353 2.819	94 0.30	4.78 -1.74	7.48 -4.55	8.84 -6.02	9.30 -6.68
Wave 0, in	-0.217 2.367	72 0.30	3.26 -3.16	5.69 -5.09	7.85 -6.34	8.72 -7.03
Wave 2, in	-0.132 2.373	74 0.30	3.25 -2.99	5.91 -5.08	7.79 -6.52	8.42 -7.28
Wave 3, in	-0.174 2.477	76 0.30	3.34 -3.07	6.27 -5.29	8.11 -6.59	9.47 -7.02
Wave 4, in	-0.256 2.654	80 0.30	3.46 -3.20	6.78 -5.66	9.15 -6.98	11.15 -7.54

TABLE 6.61

MODEL BREAKING WAVE TEST RESULTS

Boom 1.5 x 24 ft B/W = 10.3

Waves 1.4 ft Significant Height

Run(s) : 130, Speed 1.023 fps

	Mean/RMS	Osc/Buff	Avg	1/3	1/10	Extreme
Heave 0, in	-2.733 3.161	36 0.30	1.04 -6.23	5.67 -10.06	8.65 -11.48	9.42 -11.64
Heave 2, in	-0.061 2.434	28 0.30	3.43 -3.19	6.97 -5.50	8.21 -7.91	8.67 -7.92
Heave 3, in	-0.673 2.245	37 0.30	2.06 -2.96	5.67 -5.22	7.14 -6.64	7.64 -7.22
Heave 4, in	3.102 1.948	53 0.30	4.84 1.29	6.84 -1.59	8.40 -4.29	8.92 -6.28
Wave 0, in	-0.280 1.655	36 0.30	2.00 -2.06	4.54 -4.06	6.92 -5.88	7.87 -6.58
Wave 2, in	-0.169 2.001	36 0.30	2.61 -2.37	5.58 -4.74	8.17 -6.66	8.89 -7.09
Wave 3, in	-0.211 2.495	39 0.30	2.87 -2.74	6.48 -5.74	9.46 -7.52	9.96 -8.73
Wave 4, in	-0.341 2.080	44 0.30	2.17 -2.38	5.17 -4.87	7.73 -6.55	8.32 -7.14

TABLE 6.62

MODEL IRREGULAR WAVE TEST RESULTS

Boom 1.5 x 24 ft B/W = 5.0

Waves 0.50 ft Significant Height

Run(s) : 140, Speed 0.527 fps

	Mean/RMS	Osc/Buf	Avg	1/3	1/10	Extreme
Heave 0, in	-2.451 1.820	93 0.30	-0.47 -4.50	0.86 -6.39	1.99 -7.56	2.72 -8.87
Heave 2, in	1.165 1.378	87 0.30	2.71 -0.44	3.90 -1.65	4.58 -2.56	5.26 -3.58
Heave 3, in	-0.188 1.656	89 0.30	1.49 -1.87	3.14 -3.34	3.86 -4.04	5.39 -4.72
Heave 4, in	0.908 1.620	93 0.30	2.86 -1.10	4.10 -2.19	4.92 -3.07	5.98 -4.57
Wave 0, in	-0.177 1.335	91 0.30	1.48 -1.75	2.50 -2.77	3.19 -3.35	5.13 -4.22
Wave 2, in	-0.072 1.334	94 0.30	1.60 -1.53	2.70 -2.62	3.49 -3.16	4.95 -4.00
Wave 3, in	-0.138 1.373	97 0.30	1.57 -1.65	2.85 -2.70	3.72 -3.46	4.37 -4.13
Wave 4, in	-0.289 1.483	98 0.30	1.57 -1.93	2.80 -3.20	3.76 -4.01	4.42 -5.68

TABLE 6.63

MODEL IRREGULAR WAVE TEST RESULTS

Boom 1.5 x 24 ft B/W = 5.0

Waves 0.50 ft Significant Height

Run(s) : 141, Speed 1.039 fps

	Mean/RMS	Osc/Buff	Avg	1/3	1/10	Extreme
Heave 0, in	-2.300 1.783	50 0.30	-0.33 -4.33	1.10 -5.97	2.07 -7.21	2.46 -8.70
Heave 2, in	1.210 1.327	47 0.30	2.74 -0.21	3.82 -1.35	4.48 -2.47	4.86 -3.84
Heave 3, in	-0.391 1.365	45 0.30	1.12 -1.93	2.22 -3.23	2.99 -4.34	3.61 -5.82
Heave 4, in	2.486 1.117	59 0.30	3.59 1.14	4.53 0.29	5.32 -0.75	6.37 -1.86
Wave 0, in	-0.217 1.173	54 0.30	1.15 -1.52	2.14 -2.38	2.90 -3.18	3.59 -3.62
Wave 2, in	-0.094 1.211	56 0.30	1.38 -1.43	2.32 -2.40	2.96 -3.26	3.63 -3.59
Wave 3, in	-0.206 1.321	55 0.30	1.41 -1.70	2.48 -2.74	3.10 -3.49	3.59 -4.25
Wave 4, in	-0.288 1.379	57 0.30	1.29 -1.82	2.49 -2.88	3.56 -3.76	4.01 -4.10

TABLE 6.64

MODEL IRREGULAR WAVE TEST RESULTS

Boom 1.5 x 24 ft B/W = 5.0

Waves 0.75 ft Significant Height

Run(s) : 142, Speed 0.501 fps

	Mean/RMS	Osc/Buf	Avg	1/3	1/10	Extreme
Heave 0, in	-2.411 3.036	89 0.30	0.69 -5.49	3.31 -8.55	5.87 -11.31	11.55 -13.98
Heave 2, in	0.973 2.354	77 0.30	3.64 -1.60	5.71 -3.65	7.94 -5.76	10.05 -8.26
Heave 3, in	-0.905 2.477	81 0.30	1.75 -3.49	4.11 -5.56	6.35 -6.98	8.82 -9.08
Heave 4, in	0.807 2.410	96 0.30	3.17 -1.71	5.79 -3.52	7.91 -4.96	10.08 -9.52
Wave 0, in	-0.230 2.257	82 0.30	2.48 -2.55	4.38 -4.40	5.94 -6.29	8.22 -8.09
Wave 2, in	-0.104 2.326	80 0.30	2.73 -2.56	4.81 -4.48	6.32 -6.34	8.02 -8.20
Wave 3, in	-0.168 2.415	89 0.30	2.63 -2.51	4.79 -4.58	6.59 -6.36	8.71 -8.84
Wave 4, in	-0.324 2.415	87 0.30	2.60 -2.74	4.71 -4.60	6.82 -5.92	9.84 -8.41

TABLE 6.65

MODEL IRREGULAR WAVE TEST RESULTS

Boom 1.5 x 24 ft B/W = 5.0
Waves 0.75 ft Significant Height

Run(s) : 143, Speed 1.028 fps

	Mean/RMS	Osc/Buf	Avg	1/3	1/10	Extreme
Heave 0, in	-2.378 2.910	44 0.30	0.55 -5.57	3.20 -8.49	5.64 -10.72	7.82 -12.66
Heave 2, in	1.142 2.350	36 0.30	4.03 -1.64	6.07 -3.27	8.01 -5.82	9.67 -8.06
Heave 3, in	-0.454 2.203	37 0.30	2.30 -2.97	4.10 -4.65	6.16 -6.50	8.34 -7.39
Heave 4, in	2.655 1.956	53 0.30	4.46 0.66	6.12 -1.10	7.58 -2.31	11.99 -5.15
Wave 0, in	-0.252 2.211	38 0.30	2.56 -2.71	4.51 -4.32	6.14 -5.64	9.07 -6.73
Wave 2, in	-0.141 2.189	41 0.30	2.48 -2.34	4.52 -4.20	6.23 -5.77	10.33 -7.57
Wave 3, in	-0.270 2.268	39 0.30	2.60 -2.79	4.51 -4.37	6.94 -6.72	10.77 -7.97
Wave 4, in	-0.347 2.415	42 0.30	2.55 -2.87	4.57 -4.50	6.56 -6.28	12.09 -7.63

TABLE 6.66

MODEL IRREGULAR WAVE TEST RESULTS

Boom 1.5 x 24 ft B/W = 5.0

Waves 1.00 ft Significant Height

Run(s) : 144, Speed 0.538 fps

	Mean/RMS	Osc/Buff	Avg	1/3	1/10	Extreme
Heave 0, in	-3.157 3.932	77 0.30	0.93 -6.84	3.90 -10.78	5.20 -13.56	6.39 -14.75
Heave 2, in	0.752 3.075	71 0.30	4.14 -2.32	6.48 -5.13	7.52 -7.18	7.84 -9.24
Heave 3, in	-0.780 3.097	70 0.30	2.66 -3.98	5.31 -6.61	6.77 -8.20	7.63 -9.18
Heave 4, in	1.225 3.091	85 0.30	4.53 -1.95	7.31 -4.37	9.41 -5.99	10.46 -8.95
Wave 0, in	-0.177 3.020	73 0.30	3.26 -3.07	5.94 -5.50	7.22 -6.81	8.35 -7.85
Wave 2, in	-0.072 3.001	75 0.30	3.35 -3.00	5.95 -5.53	7.75 -7.07	9.69 -7.91
Wave 3, in	-0.161 3.103	72 0.30	3.70 -3.17	6.29 -5.81	8.26 -7.11	10.08 -7.76
Wave 4, in	-0.348 3.167	74 0.30	3.46 -3.56	6.19 -6.02	7.94 -7.54	8.71 -7.80

TABLE 6.67

MODEL BREAKING WAVE TEST RESULTS

Boom 1.5 x 24 ft B/W = 5.0

Waves 1.4 ft Significant Height

Run(s) : 145, Speed 0.538 fps

	Mean/RMS	Osc/Buff	Avg	1/3	1/10	Extreme
Heave 0, in	-1.912 3.431	71 0.30	2.56 -6.17	6.31 -9.05	7.92 -11.24	9.67 -12.53
Heave 2, in	1.268 2.528	73 0.30	4.60 -1.80	6.88 -4.11	8.25 -5.51	9.50 -6.07
Heave 3, in	0.219 2.800	75 0.30	3.87 -2.68	6.82 -4.80	8.25 -6.40	9.07 -7.13
Heave 4, in	0.863 2.870	85 0.30	4.48 -2.63	7.32 -5.17	8.44 -6.46	8.66 -7.06
Wave 0, in	-0.195 2.351	71 0.30	3.24 -3.12	5.61 -4.97	7.31 -6.15	9.32 -6.95
Wave 2, in	-0.086 2.359	73 0.30	3.27 -2.90	5.79 -4.87	7.43 -6.44	8.63 -7.15
Wave 3, in	-0.161 2.524	75 0.30	3.40 -3.11	6.23 -5.30	7.79 -6.79	10.06 -7.22
Wave 4, in	-0.292 2.676	79 0.30	3.27 -3.27	6.57 -5.71	8.69 -7.14	10.10 -7.95

TABLE 6.68

MODEL BREAKING WAVE TEST RESULTS

Boom 1.5 x 24 ft B/W = 5.0

Waves 1.4 ft Significant Height

Run(s) : 146, Speed 1.029 fps

	Mean/RMS	Osc/Buff	Avg	1/3	1/10	Extreme
Heave 0, in	-2.481 3.152	32 0.30	1.83 -6.41	6.25 -10.16	8.94 -12.00	9.61 -12.90
Heave 2, in	1.090 2.244	30 0.30	4.70 -1.70	7.39 -3.94	8.28 -5.93	8.60 -6.23
Heave 3, in	-0.299 2.474	35 0.30	3.04 -2.74	6.75 -4.68	8.18 -6.04	8.60 -6.57
Heave 4, in	2.399 1.795	51 0.30	4.02 0.64	6.31 -1.71	7.82 -3.93	8.69 -5.16
Wave 0, in	-0.259 1.564	38 0.30	1.74 -1.98	4.07 -3.89	6.12 -5.52	6.36 -5.63
Wave 2, in	-0.115 2.069	33 0.30	3.04 -2.72	5.84 -4.87	8.31 -6.62	8.55 -6.89
Wave 3, in	-0.221 2.517	37 0.30	3.18 -3.04	6.89 -5.81	9.53 -7.73	10.25 -8.70
Wave 4, in	-0.392 1.993	44 0.30	2.04 -2.25	4.88 -4.54	7.49 -6.57	7.69 -7.11

TABLE 7.1
ROUGH WATER DRAG RESULTS
Predicted Full Scale Values

Run	Scale	Boom Configuration			Type	Wave Configuration		Speed knot	Drag lb
		Height ft	Length ft	Gap Length		Height ft	Length ft		
50	1/8	4	192	1/3	Regular	4	48	0	527
51								0.5	641
52								1.0	1314
53								2.0	4002
54					Regular	8	96	0.5	946
55					Regular	12	144	1.0	1135
56								0.5	1033
57					Irregular	4	---	0.9	1802
58								0.5	125
59					Irregular	6	---	1.0	407
61								0.5	162
62					Irregular	8	---	1.0	1068
60					Breaking	11.3	---	0.5	413
63								0.5	604
64								0.9	1227
80	1/8	4	192	1/3	Regular	4	48	0	950
81								0.5	756
82								1.0	1329
83								1.9	3384
84					Regular	8	96	0.5	780
85					Regular	12	144	1.0	1482
86								0.5	1254
87					Irregular	4	---	0.9	2134
88								0.5	82
89					Irregular	6	---	1.0	375
90								0.5	357
91					Irregular	8	---	1.0	710
92					Breaking	11.3	---	0.5	395
93								0.5	923
94								1.0	1519

TABLE 7.2
ROUGH WATER DRAG RESULTS
Predicted Full Scale Values

Run	Scale	Boom Configuration		B/W	Type	Wave Configuration		Speed	Drag
		Height ft	Length ft			Height ft	Length ft		
65	1/8	4	192	1/3	9.6	Regular	4	48	3.06
66									0
67									356
68									938
69									1436
70									2.0
71									3536
72									0.5
73									937
74									1.0
75									1524
76									0.5
77									1145
78									2163
79									1.0
									0.5
									139
									622
									1.0
									0.5
									395
									1.0
									763
									0.5
									288
									0.5
									675
									1.0
									1379
1	1/4	4	96	1/3	34.3	Regular	2	24	2.17
2									0
3									112
4									227
5									524
6									1920
7									0.5
8									205
9									488
10									0.9
11									1.0
12									509
13									0.5
14									241
15									1.0
									619
									0.5
									94
									1.0
									447
									0.5
									107
									1.0
									435
									0.5
									126
									0.5
									176
									1.0
									490

TABLE 7.3
ROUGH WATER DRAG RESULTS
Predicted Full Scale Values

Run	Scale	Boom Configuration			B/W	Wave Configuration			Speed knot	Drag lb
		Height ft	Length ft	Gap Length		Type	Height ft	Length ft		
17	1/4	4	96	1/3	10.4	Regular	2	24	0	80
18									0.5	236
19									0.9	659
20									2.0	2345
21						Regular	4	48	0.5	327
22									1.0	710
23						Regular	6	72	0.5	358
26									0.5	372
24									1.0	921
25									1.0	927
27						Irregular	2	---	0.5	93
28									1.0	492
29	1/4				4.4	Irregular	3	---	0.5	147
30									1.0	518
31						Breaking	5.6	---	0.5	317
32									1.0	691
33						Regular	2	24	0	108
34									0.5	369
35									0.9	812
36									2.0	2807
37						Regular	4	48	0.5	437
38									1.0	1011
39						Regular	6	72	0.5	503
40	1/4								1.0	1208
41						Irregular	2	---	0.5	170
42									1.0	664
43						Irregular	3	---	0.5	182
44									1.0	718
45						Breaking	5.6	---	0.5	283
46									1.0	878

TABLE 7.4
ROUGH WATER DRAG RESULTS
Predicted Full Scale Values

Run	Scale	Boom Configuration		B/W	Type	Wave Configuration		Period Max En	Speed knot	Drag lb
		Height ft	Length ft			Height ft	Length ft			
164	1/4	4	48	2/3	Regular	2	24	2.17	0	89
150									0.6	335
151									0.9	692
152									1.9	1926
153					Regular	4	48	3.08	0.6	419
154									1.0	794
155					Regular	6	72	3.86	0.5	415
156									1.0	1064
157					Irregular	2	---	3.91	0.5	220
158					Irregular	3	---	4.79	1.0	620
159	3/8								0.5	250
160					Irregular	4	---	5.54	1.0	718
161					Breaking	5.6	---	3.0	0.5	292
162									0.5	399
163									1.0	836
99		4	64	1/3	Regular	1.3	16	1.77	0	28
100									0.5	136
101									1.0	436
102					Regular	2.7	32	2.51	2.2	2198
104									0.5	145
105					Regular	4	48	3.15	1.0	510
106									0.6	206
107					Irregular	1.3	---	3.20	1.0	467
108					Irregular	2	---	3.91	0.5	100
109									1.0	346
110					Irregular	2.7	---	4.52	0.5	85
111					Breaking	3.7	---	2.4	1.0	369
112									0.5	112
113									0.5	156
115									1.0	422

TABLE 7.5
ROUGH WATER DRAG RESULTS
Predicted Full Scale Values

Run	Scale	Boom Configuration			Type	Wave Configuration			Speed knot	Drag lb
		Height ft	Length ft	Gap Length		Height ft	Length ft	Period Max En sec		
116	3/8	4	64	1/3	Regular	1.3	16	1.77	0	37
117									0.5	181
118									1.0	574
119					Regular	2.7	32	2.51	1.9	1847
120									0.5	223
121									1.0	623
122					Regular	4	48	3.15	0.5	292
123									1.0	675
124									0.5	110
125					Irregular	1.3	---	3.20	1.0	429
126									0.5	140
127									1.0	458
128					Irregular Breaking	2.7	---	4.52	0.5	147
129									0.5	199
130									1.0	493
131	3/8	4	64	1/3	Regular	1.3	16	1.77	0	32
132									0.5	226
133									1.0	661
134					Regular	2.7	32	2.51	1.9	2016
135									0.5	313
136									1.0	716
137					Regular	4	48	3.15	0.5	417
139									1.0	908
140									0.5	159
141					Irregular	1.3	---	3.20	1.0	533
142									0.5	174
143									1.0	560
144					Irregular Breaking	2.7	---	4.52	0.5	220
145									0.5	243
146									1.0	627

TABLE 8

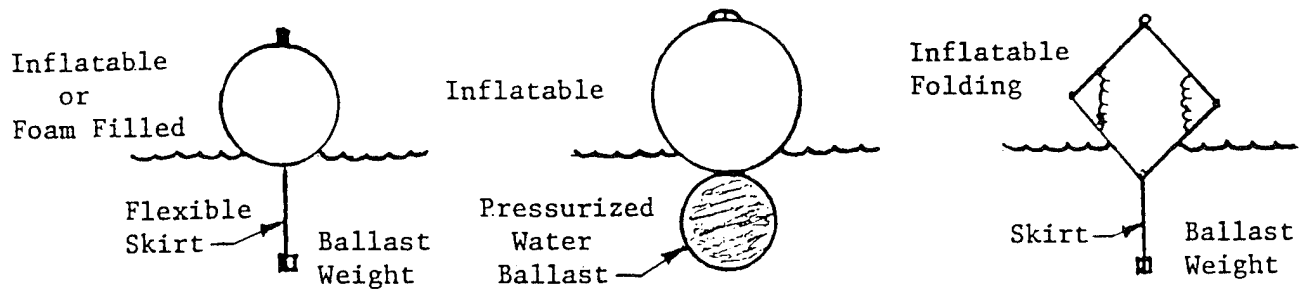
CALM WATER DRAG RESULTS
Predicted Full Scale Values

Scale	Boom Configuration			B/W	Speed	Drag
	Height ft	Length ft	<u>Gap</u> Length			
1/8	4	192	1/3	16.2	1.0	154
					2.2	2107
					3.4	Sinks
1/4	4	96	1/3	34.3	2.0	1624
					2.9	3808
1/4	4	48	2/3	9.9	0.4	103
					0.9	450
					1.7	1644
3/8	4	64	1/3	33.6	1.0	330
					1.8	1248
					2.0	1481

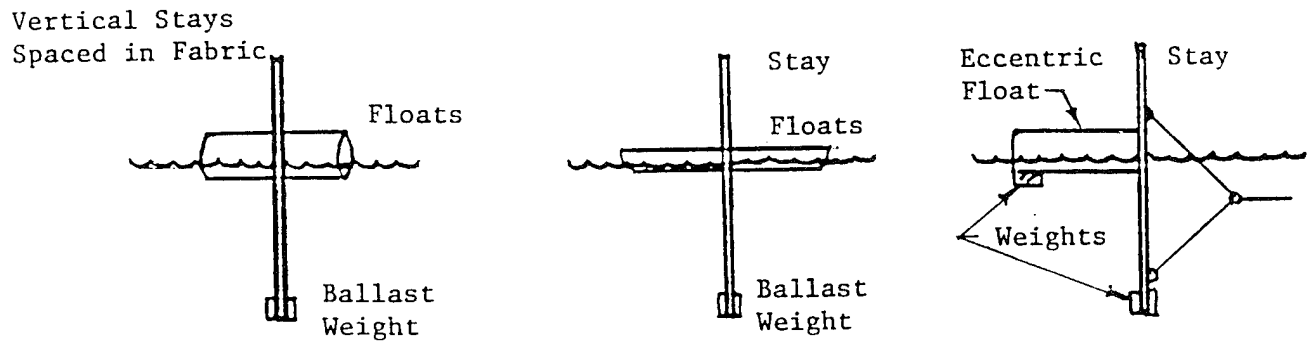
TABLE 9

COMPARISONS OF DRAG AND CENTERLINE HEAVE RESPONSE
All Booms Scaled to 4 ft Height in Regular 12:1 L/H Waves

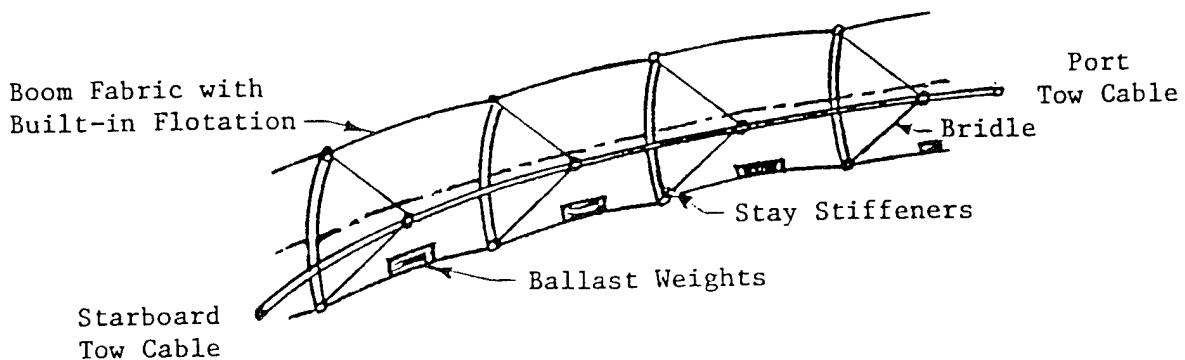
Run	Scale	Boom Configuration			Wave Height ft	Speed knot	Test Results	
		Length ft	$\frac{\text{Gap}}{\text{Length}}$	B/W			Drag lb	$\frac{\text{RMS Heave}}{\text{RMS Wave}}$ 0
Effects of Scale and Speed at B/W = 10								
66	1/8	192	1/3	9.6	4	0.5	938	1.45
21	1/4	96	1/3	10.4	4	0.5	327	1.41
122	3/8	64	1/3	10.3	4	0.5	292	1.27
67	1/8	192	1/3	9.6	4	1.0	1436	1.45
22	1/4	96	1/3	10.4	4	1.0	710	1.47
123	3/8	64	1/3	10.3	4	1.0	675	1.49
Effects of B/W Ratio and Speed								
6	1/4	96	1/3	34.3	4	0.5	205	1.38
21	1/4	96	1/3	10.4	4	0.5	327	1.41
37	1/4	96	1/3	4.4	4	0.5	437	1.82
7	1/4	96	1/3	34.3	4	1.0	509	1.39
22	1/4	96	1/3	10.4	4	1.0	710	1.47
38	1/4	96	1/3	4.4	4	1.0	1011	1.65
Effects of Wave Height and Speed at B/W = 10								
66	1/8	192	1/3	9.6	4	0.5	938	1.45
69	1/8	192	1/3	9.6	8	0.5	937	1.36
71	1/8	192	1/3	9.6	12	0.5	1145	1.22
67	1/8	192	1/3	9.6	4	1.0	1436	1.45
70	1/8	192	1/3	9.6	8	1.0	1524	1.32
72	1/8	192	1/3	9.6	12	1.0	2163	1.26
Effects of Gap/Length Ratio and Speed at B/W = 10								
21	1/4	96	1/3	10.4	4	0.5	327	1.41
153	1/4	48	2/3	9.9	4	0.6	419	1.36
22	1/4	96	1/3	10.4	4	1.0	710	1.47
154	1/4	48	2/3	9.9	4	1.0	794	1.39



Curtain Boom Sections

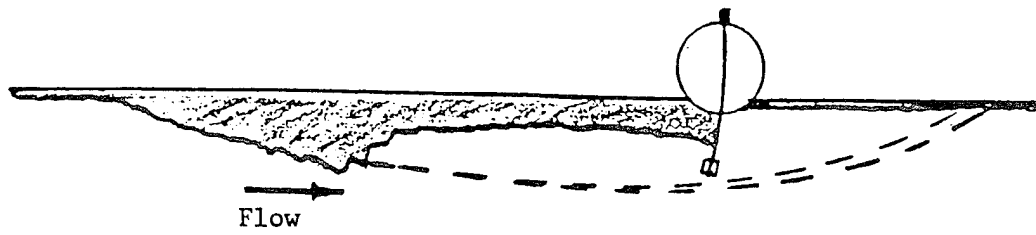


Fence Boom Sections



External Tension Boom

FIGURE 1A TYPICAL TYPES OF BOOMS



Entrainment Due to Excess Velocity ($V > 1$ knot)



Drainage Due to Excess Oil and Velocity



Splashover in Breaking Waves Due to Freeboard



Broaching in Waves - Tension Too High, Heave Not Stiff Enough

FIGURE 2A PRINCIPAL BOOM FAILURE MODES

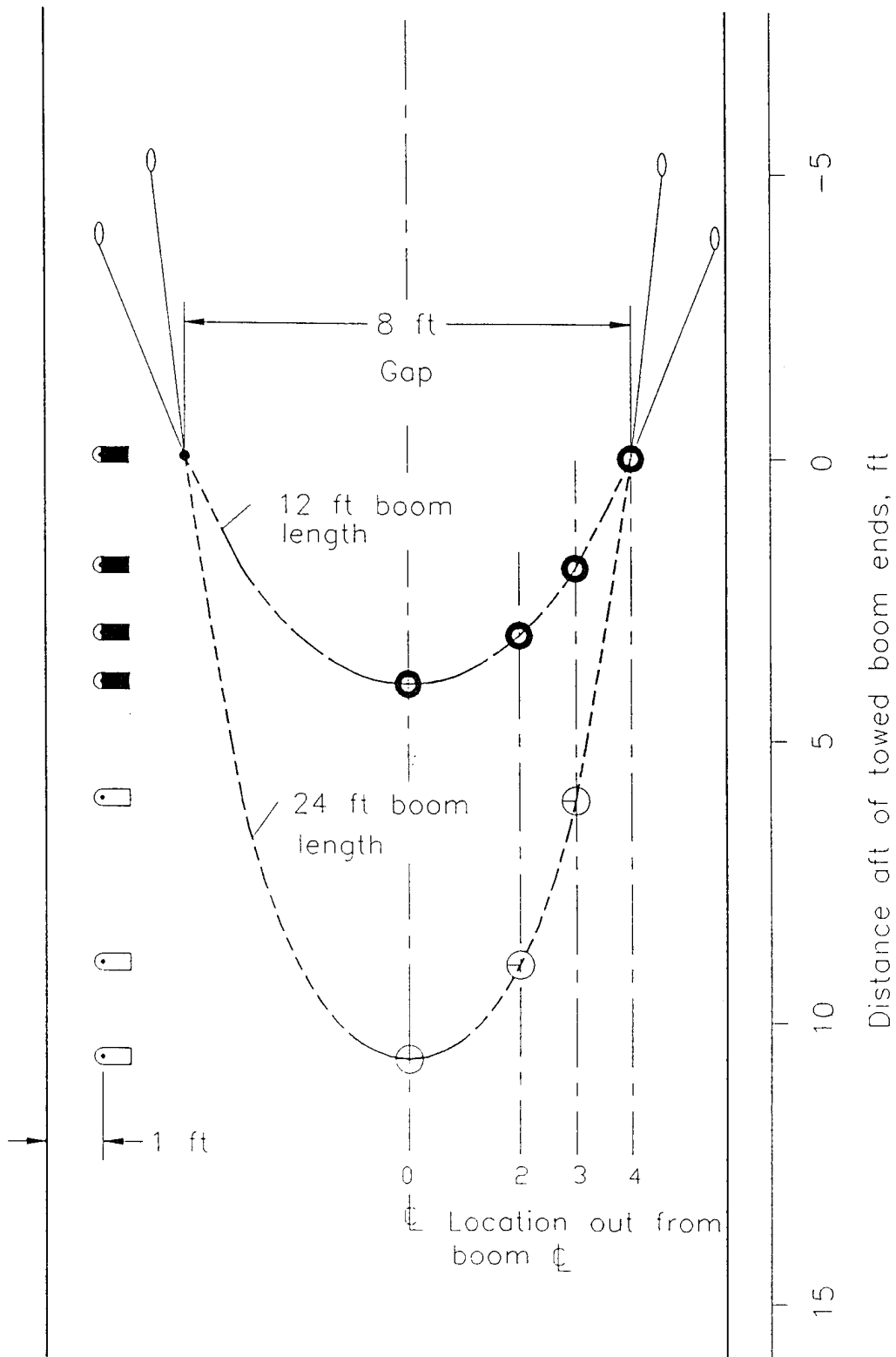


FIGURE 1 CATENARY TOW MODEL DIMENSIONS

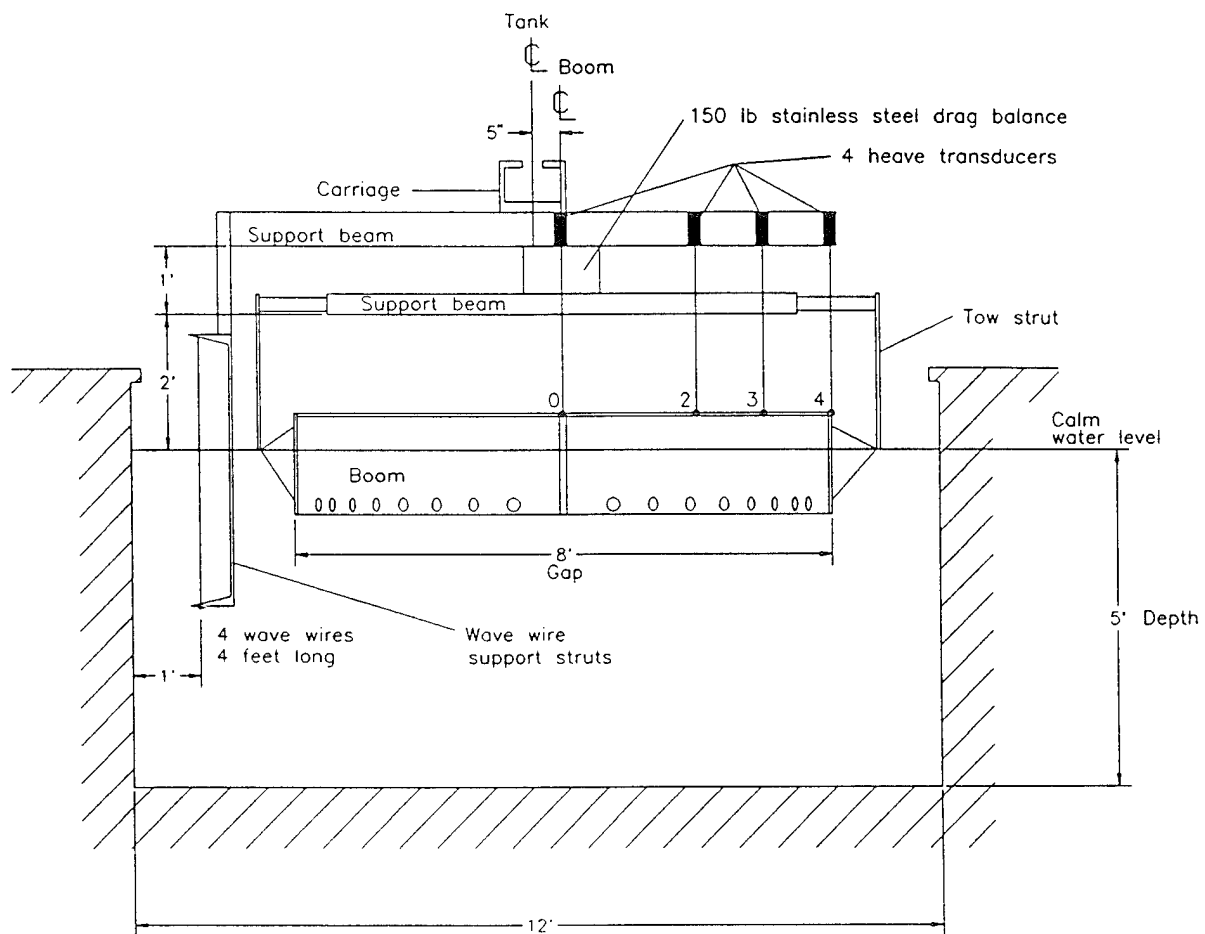
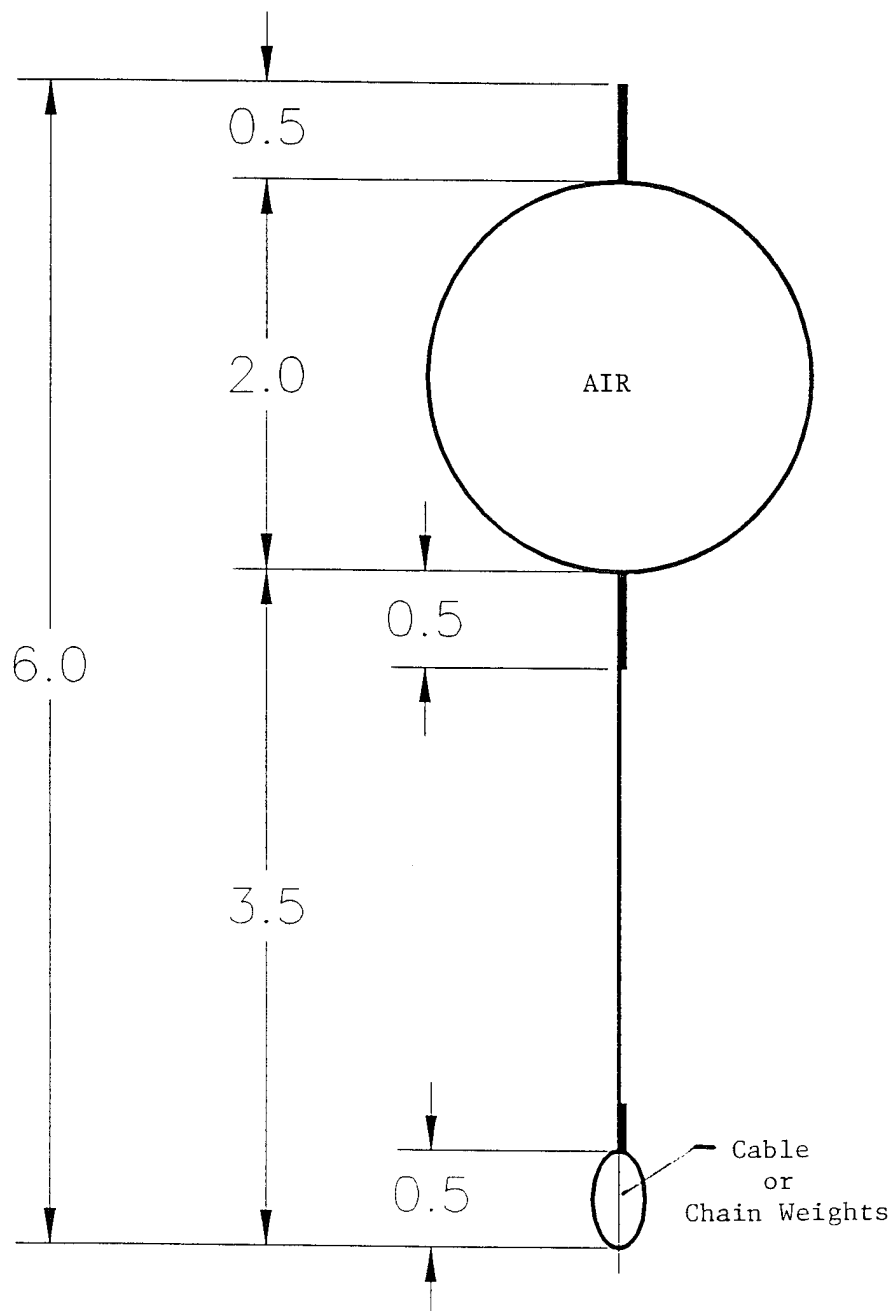
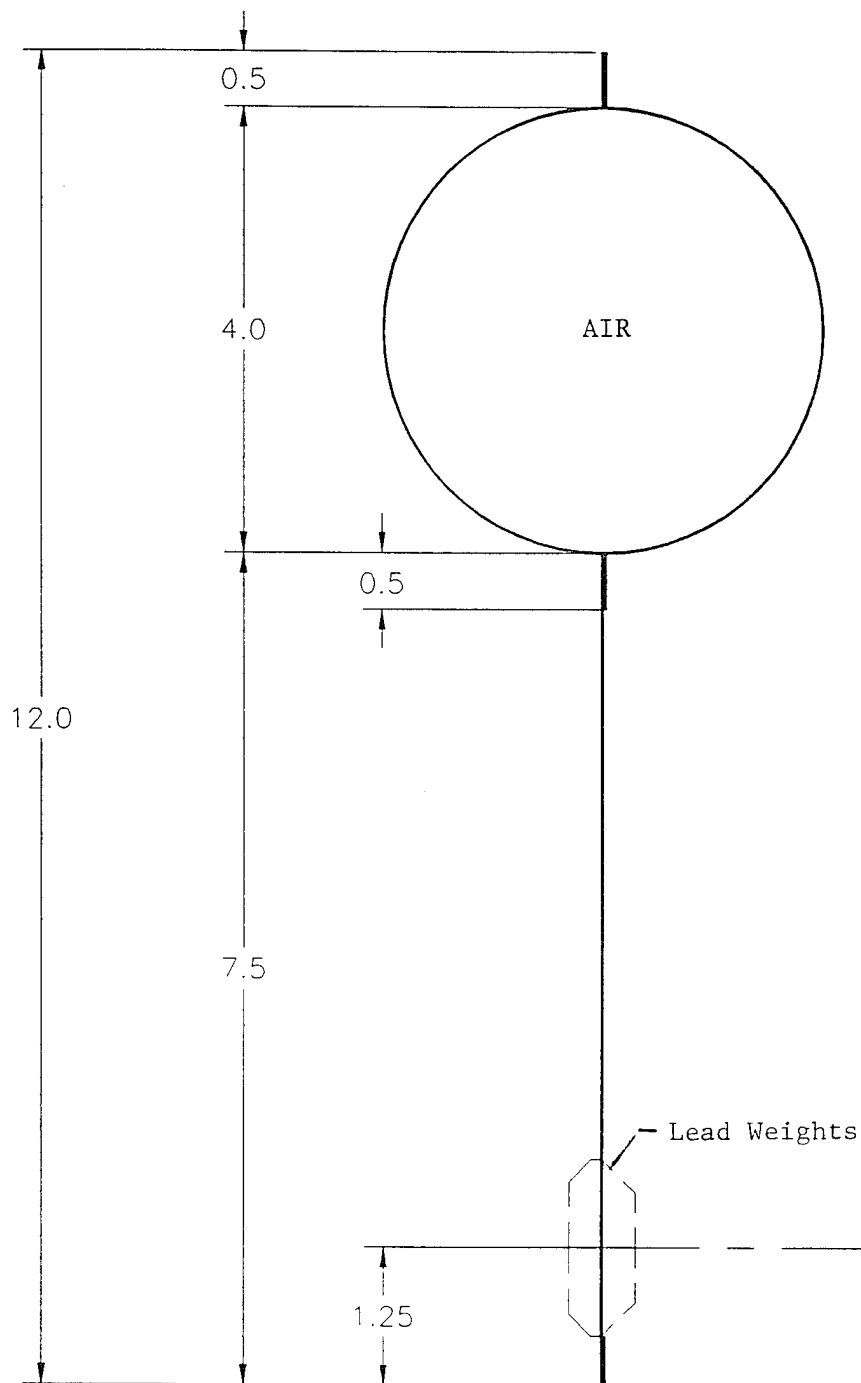


FIGURE 2 SECTIONAL VIEW OF MODEL TOW SETUP



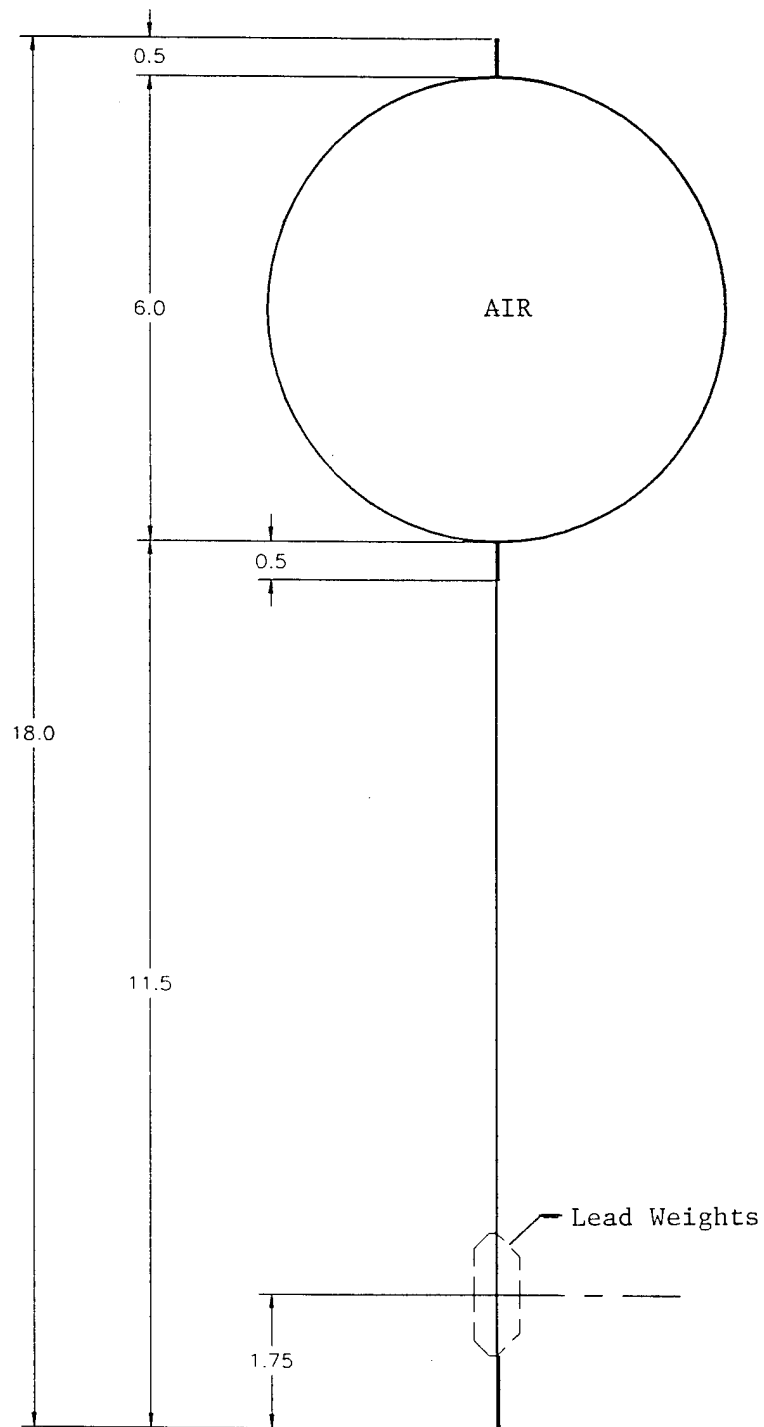
Dimensions are inches model scale

FIGURE 3 SECTION OF 0.5 FT MODEL BOOM



Dimensions are inches model scale

FIGURE 4 SECTION OF 1.0 FT MODEL BOOM



Dimensions are inches model scale

FIGURE 5 SECTION OF 1.5 FT MODEL BOOM

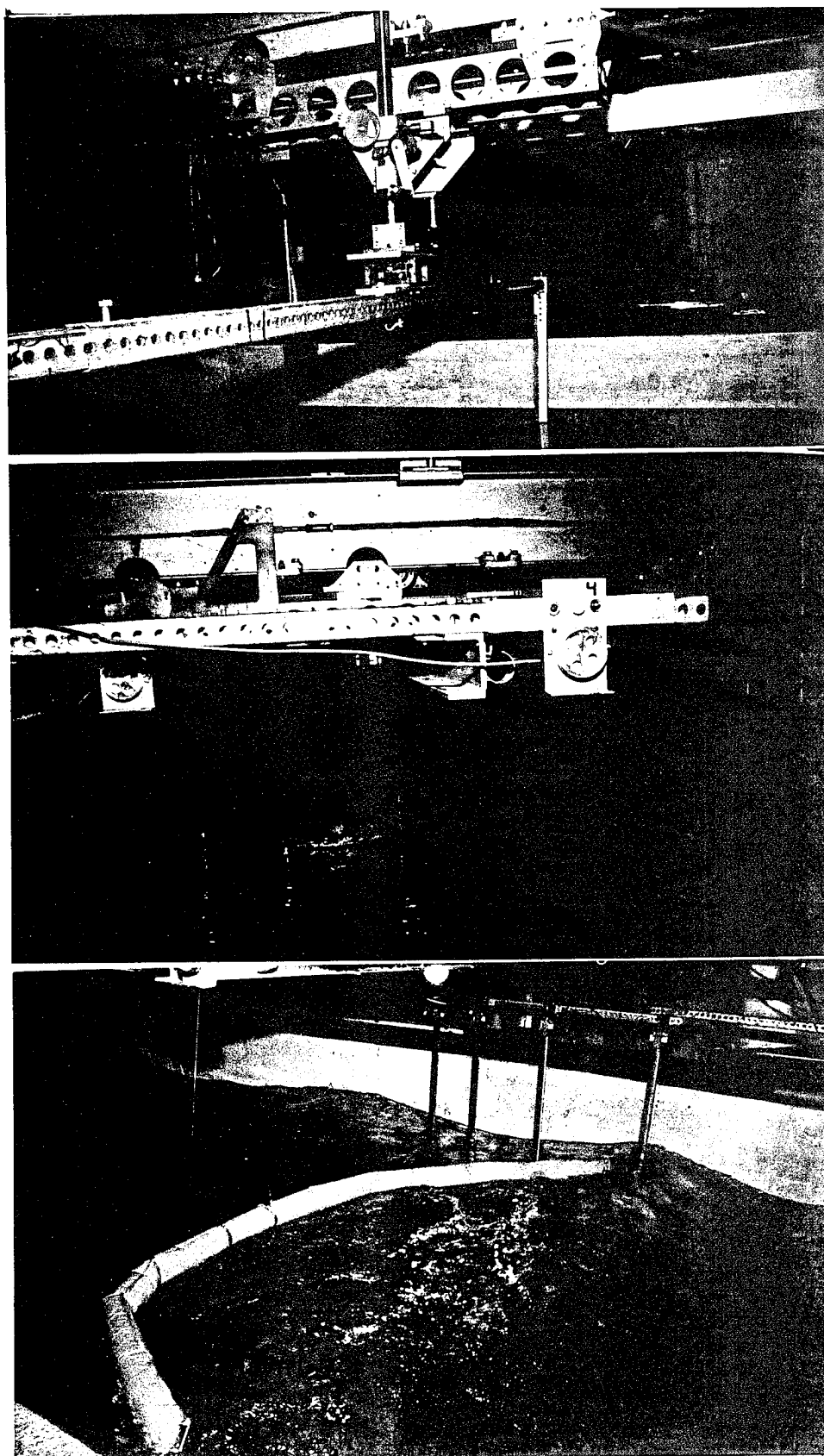


FIGURE 6 TOW RIG WITH DRAG BALANCE, HEAVE TRANSDUCER
AND WAVE STRUTS SET FOR 12 FT BOOM LENGTH

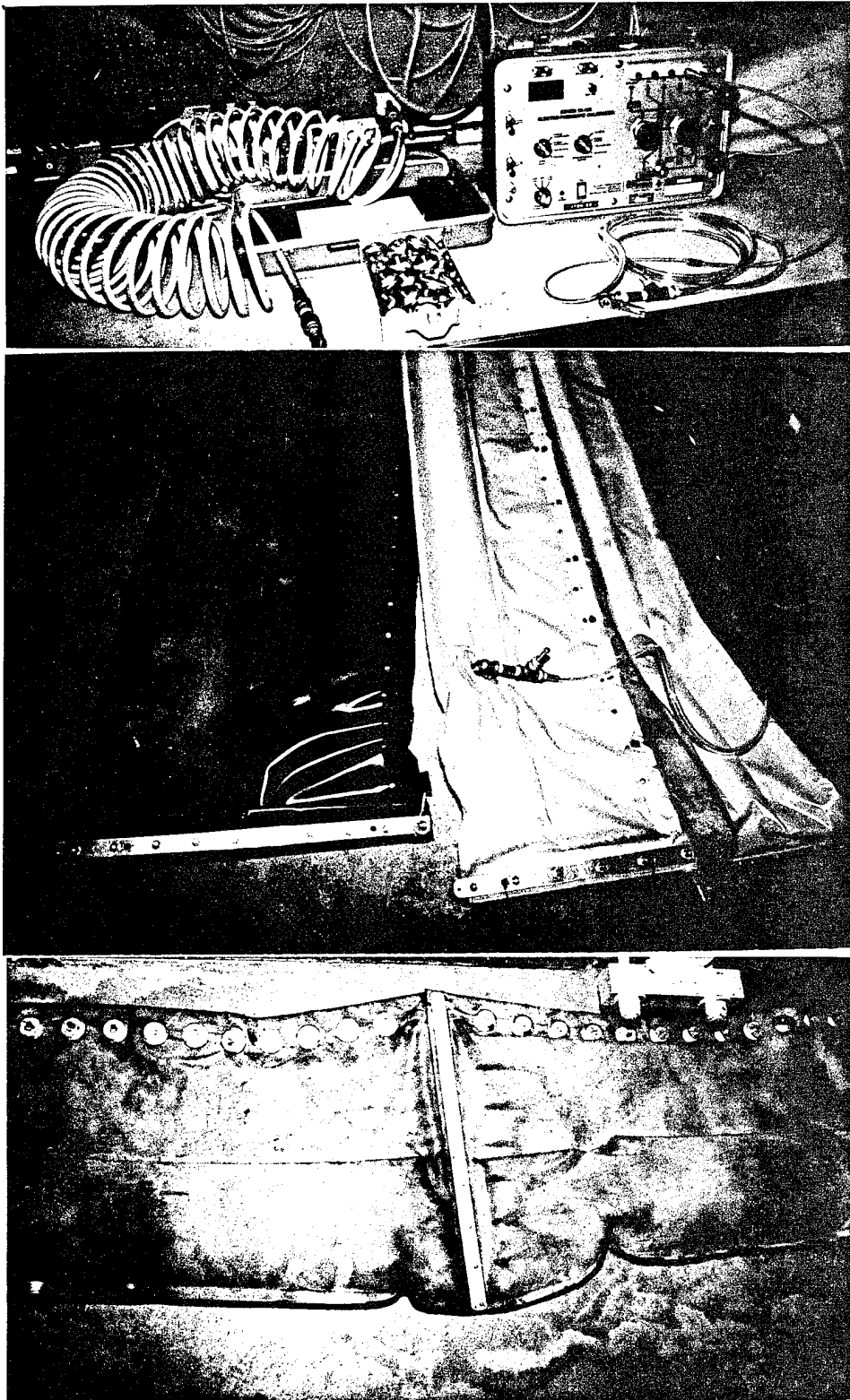


FIGURE 7 PRESSURE SYSTEM, BOOMS AND WEIGHTS

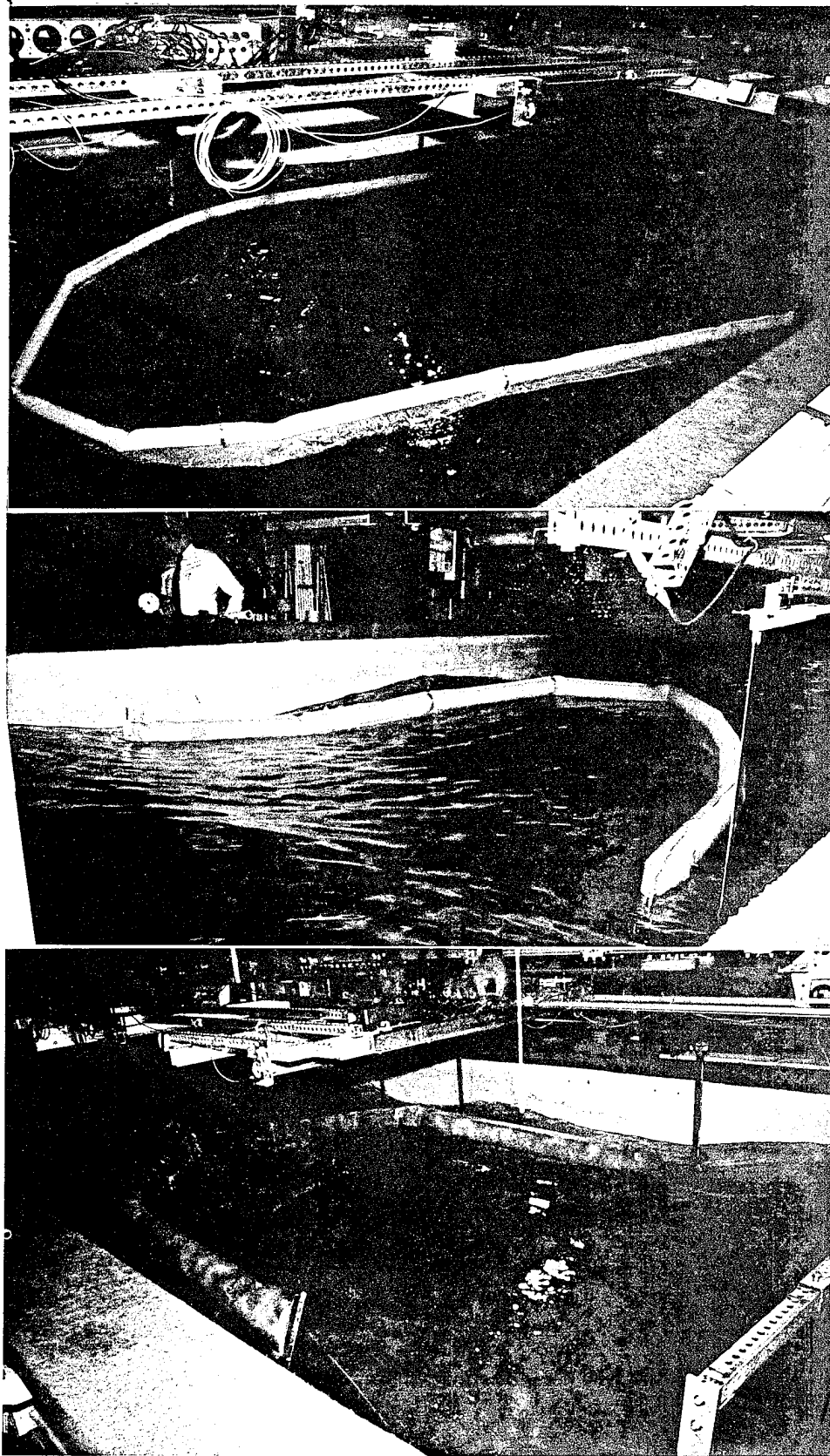
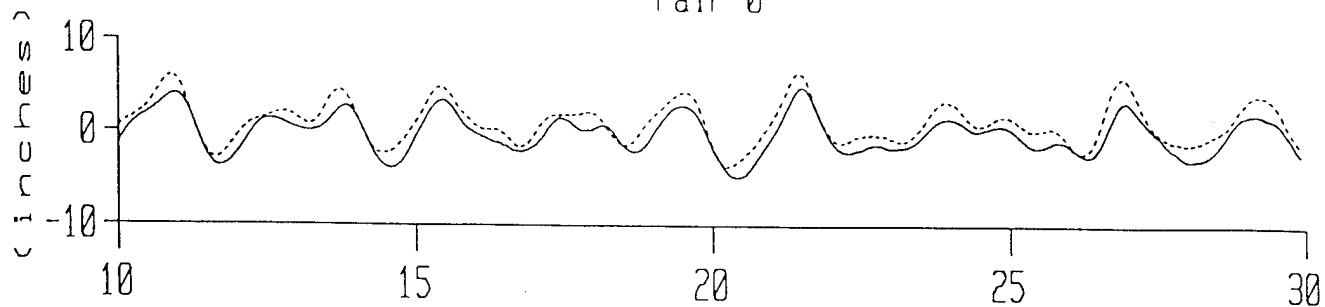


FIGURE 8 THREE SCALE BOOMS UNDER TEST

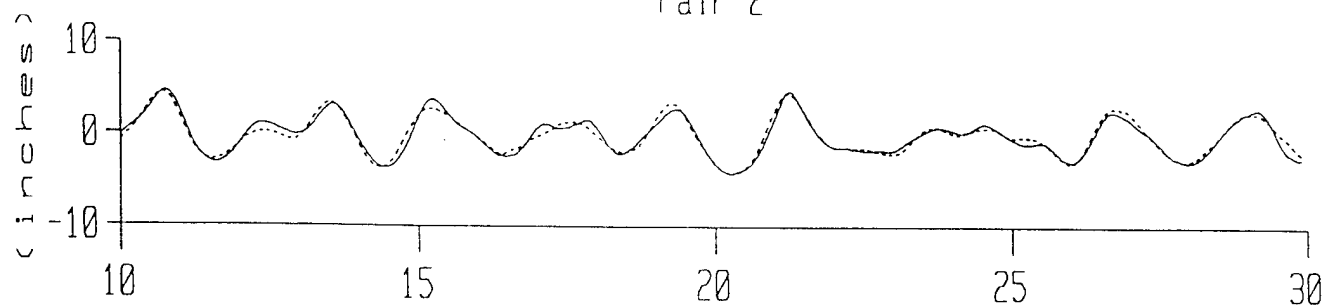
0.5 ft x 24 ft Boom at B/W = 16.2 at 0.303 fps - Run 61

0.75 ft Significant Height Irregular Waves

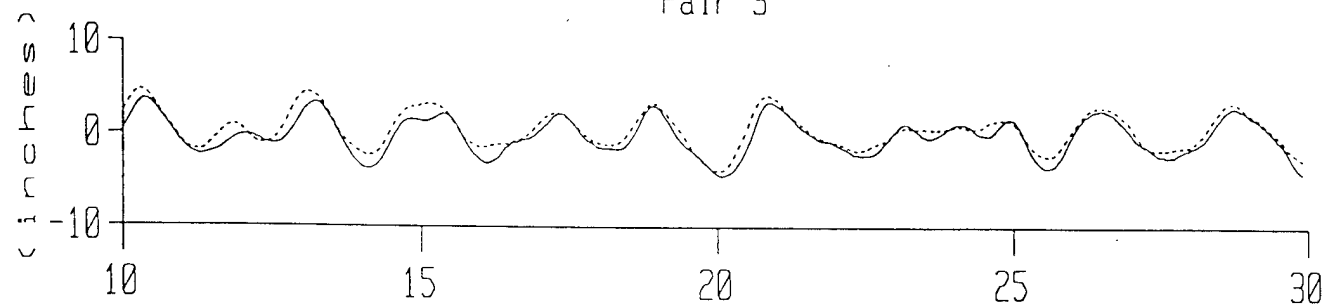
Pair 0

Wave —
Heave - - -

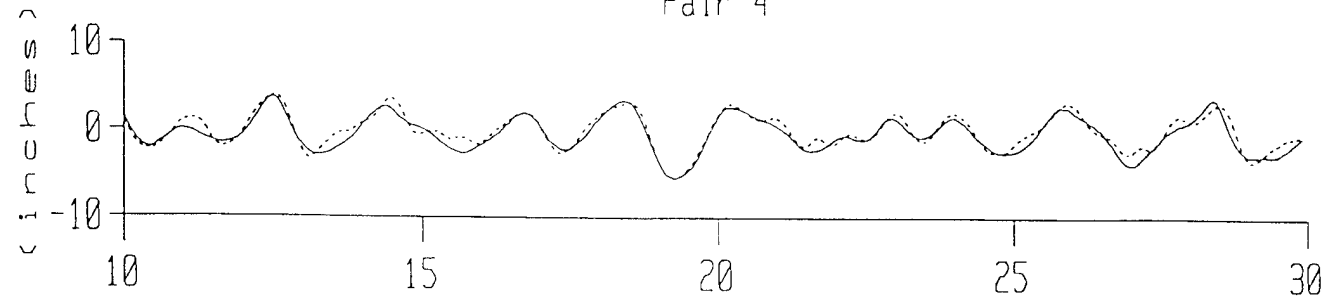
Pair 2



Pair 3



Pair 4



Time (sec)

FIGURE 9 COMPARISONS OF HEAVE AND WAVE MODEL MEASUREMENTS

0.5 ft x 24 ft Boom at B/W = 12.5 at 0.303 fps - Run 90
0.75 ft Significant Height Irregular Waves

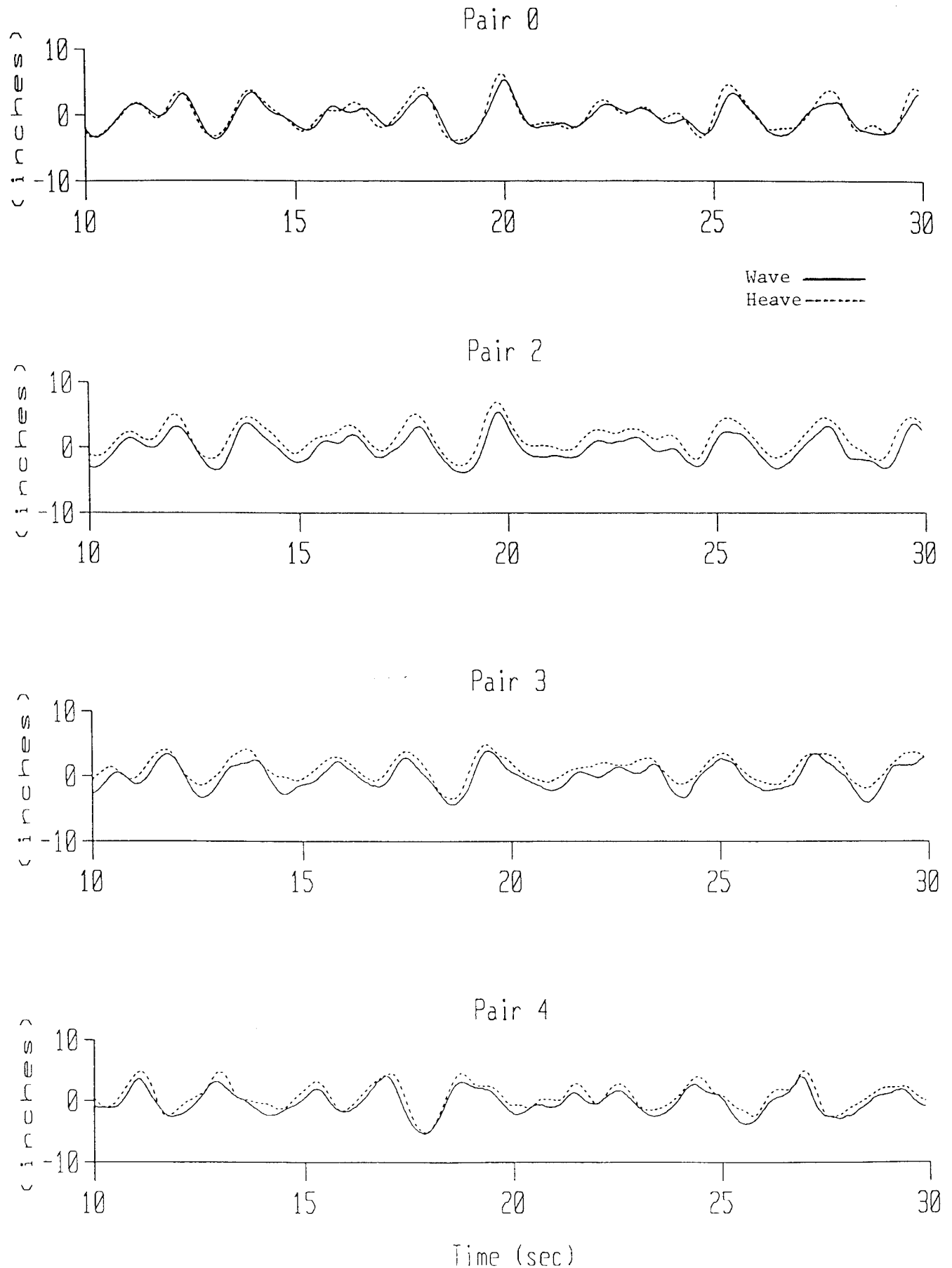


FIGURE 10 COMPARISONS OF HEAVE AND WAVE MODEL MEASUREMENTS

0.5 ft x 24 ft Boom at B/W = 9.6 at 0.304 fps - Run 75
0.75 ft Significant Height Irregular Waves

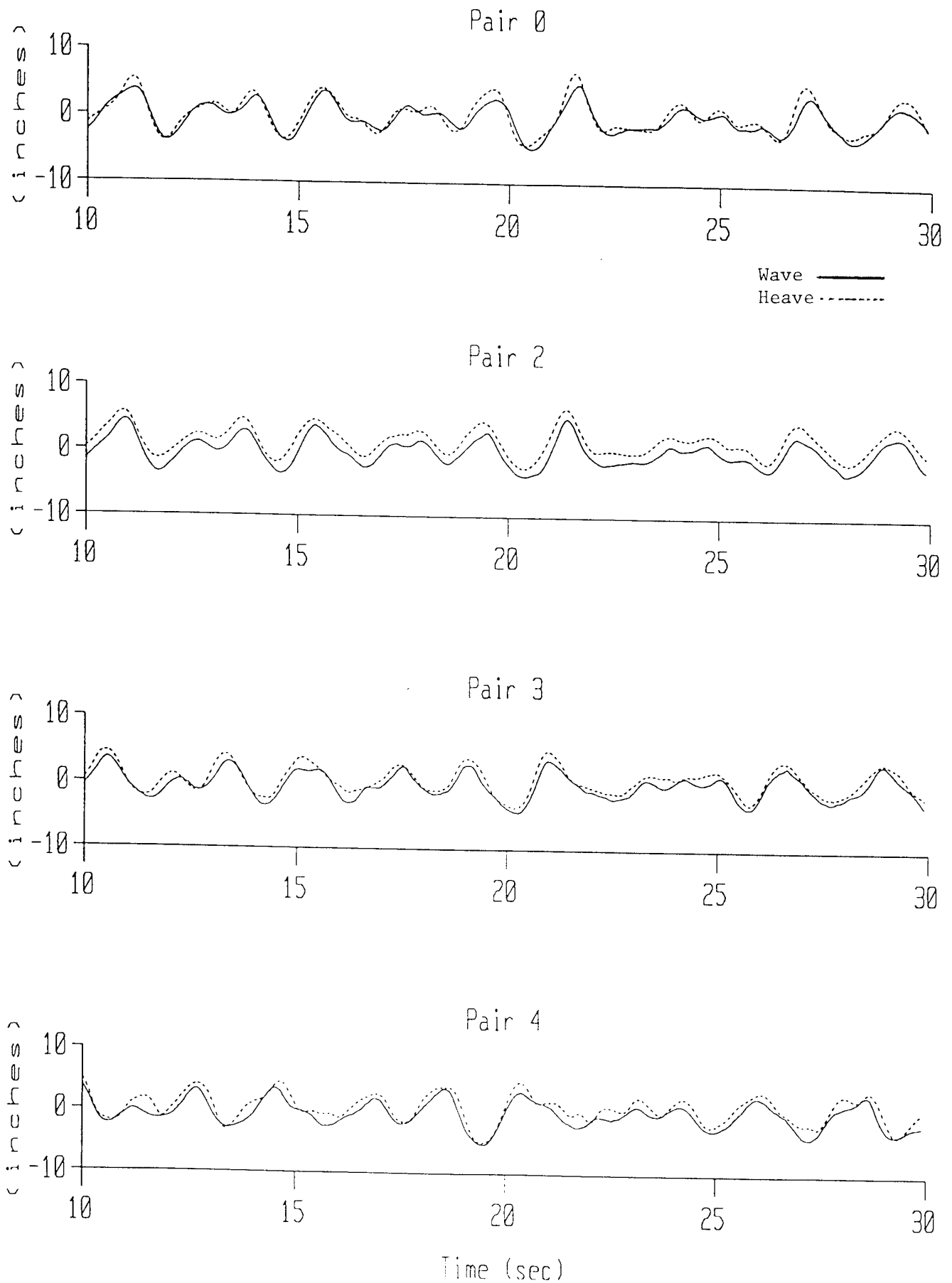


FIGURE 11 COMPARISONS OF HEAVE AND WAVE MODEL MEASUREMENTS

1.0 ft x 24 ft Boom at B/W = 34.3 at 0.397 fps - Run 13
0.75 ft Significant Height Irregular Waves

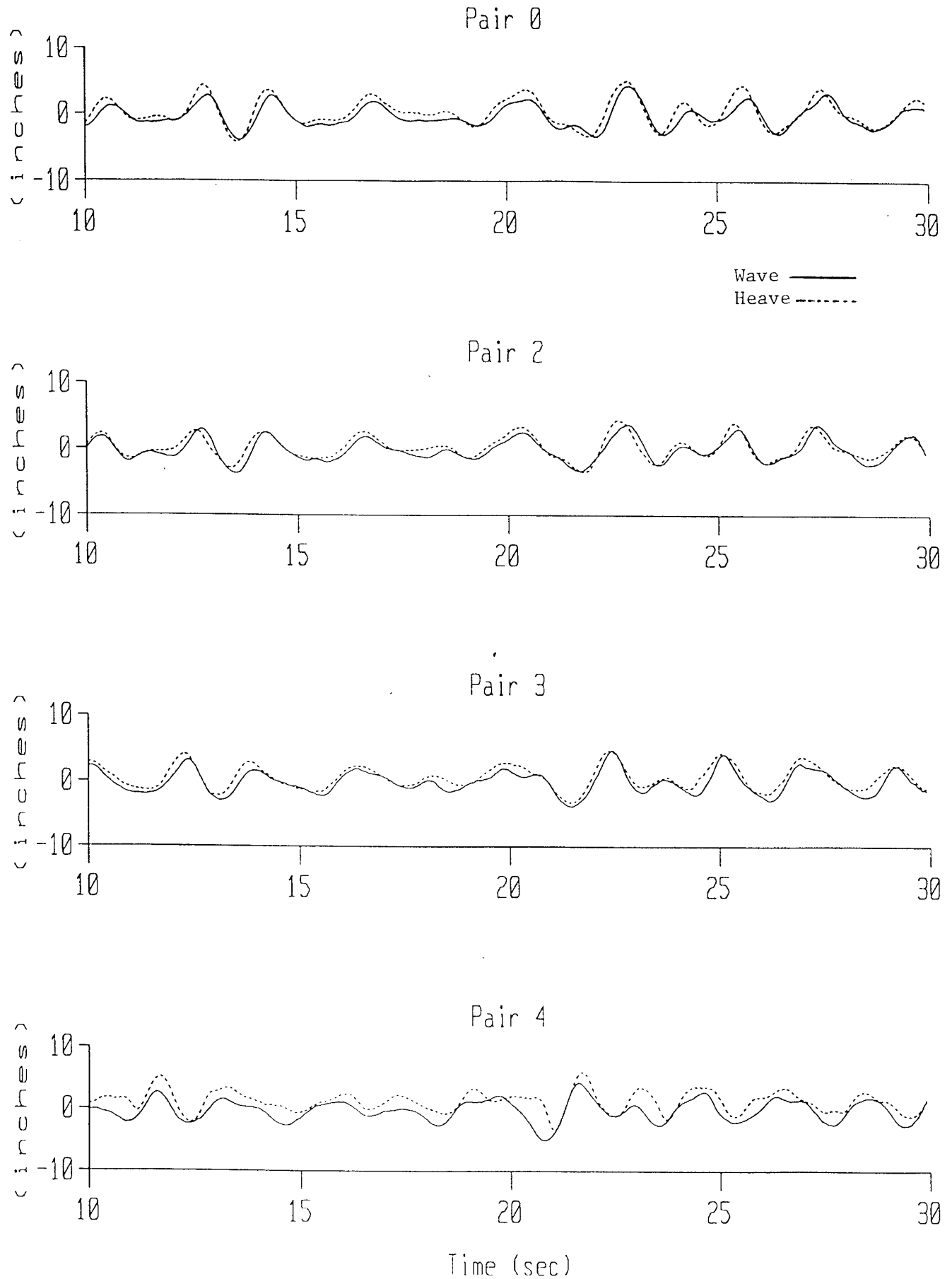


FIGURE 12 COMPARISONS OF HEAVE AND WAVE MODEL MEASUREMENTS

1.0 ft x 24 ft Boom at B/W = 10.4 at 0.396 fps - Run 29
0.75 ft Significant Height Irregular Waves

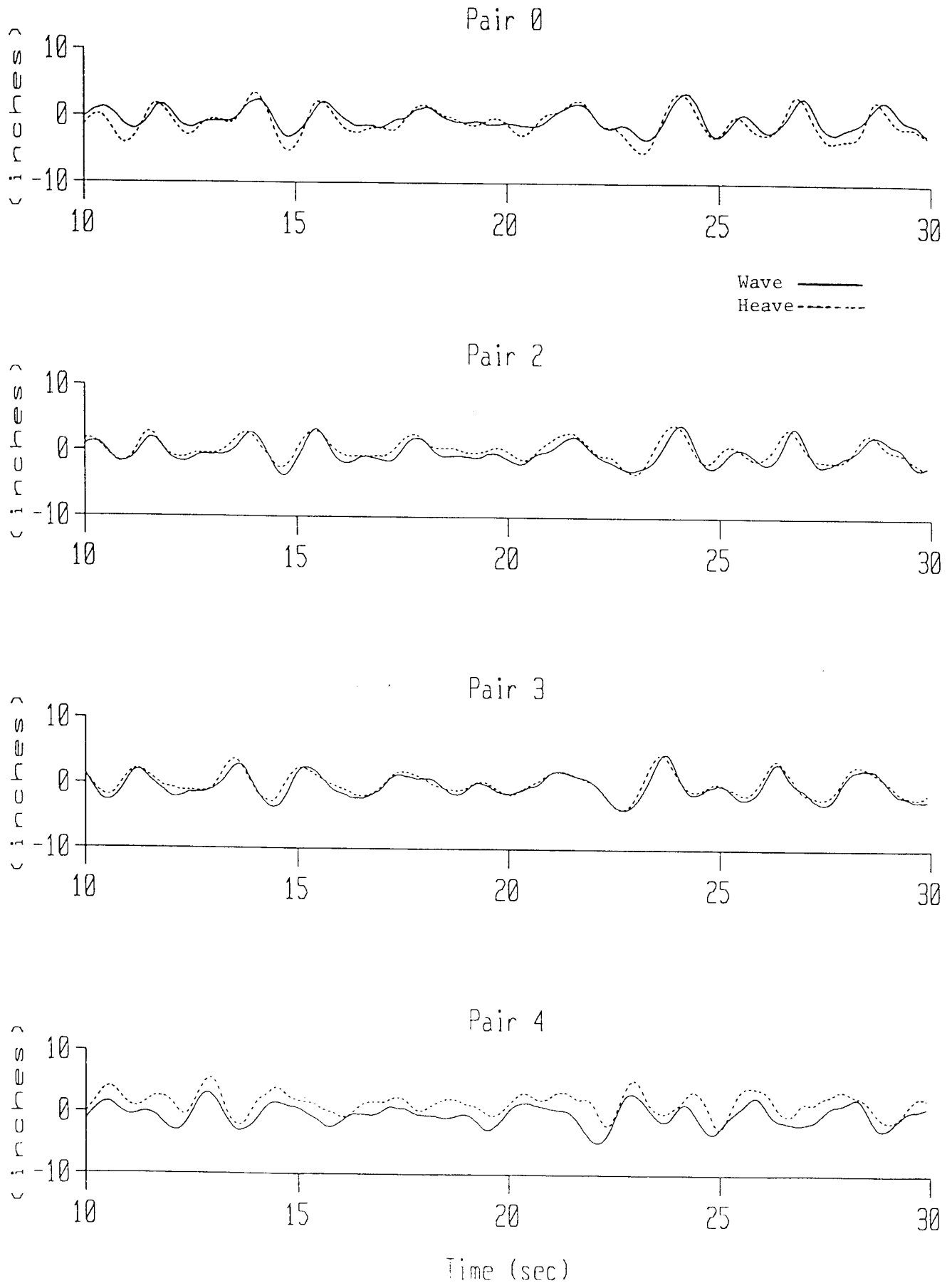


FIGURE 13 COMPARISONS OF HEAVE AND WAVE MODEL MEASUREMENTS

1.0 ft x 24 ft Boom at B/W = 4.4 at 0.398 fps - Run 43
0.75 ft Significant Height Irregular Waves

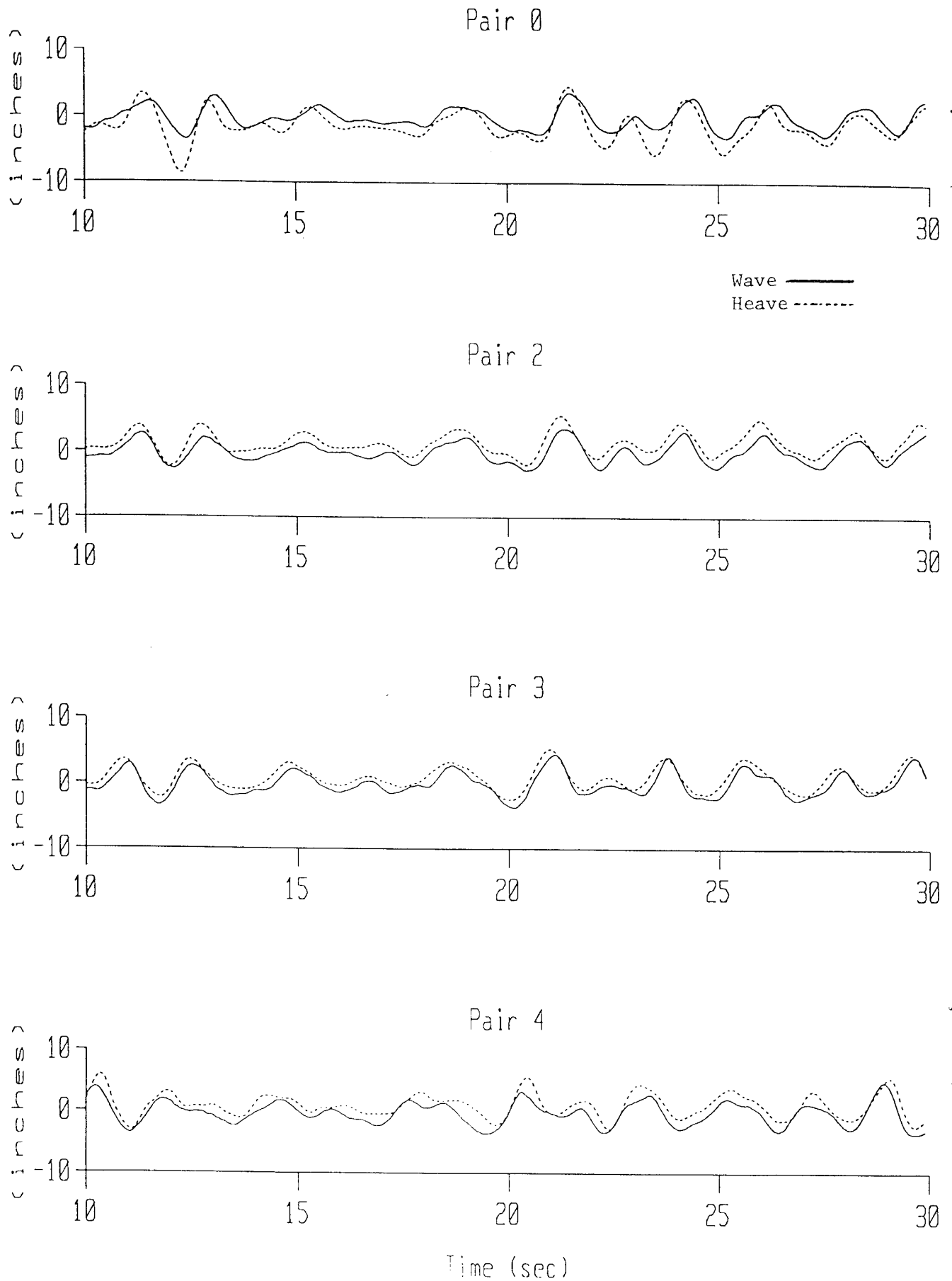
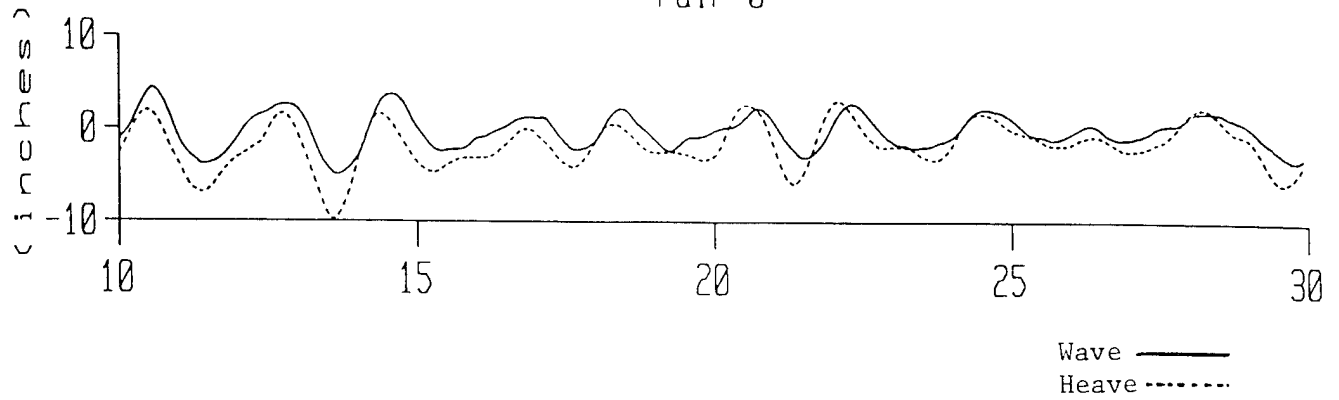


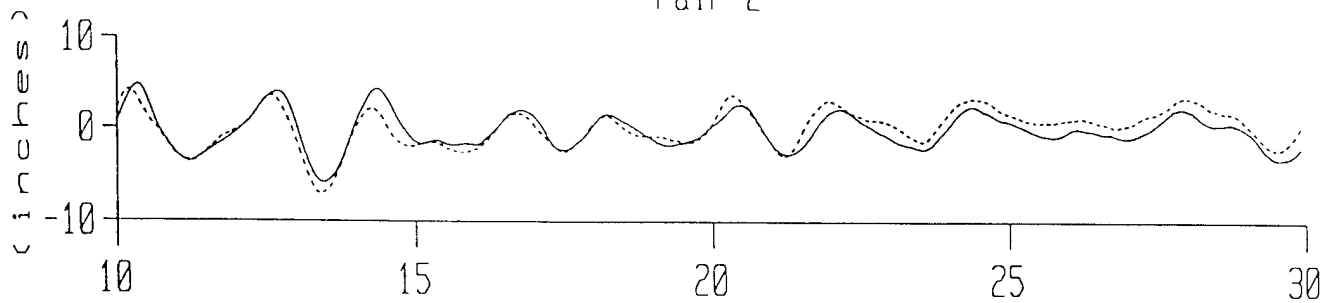
FIGURE 14 COMPARISONS OF HEAVE AND WAVE MODEL MEASUREMENTS

1.5 ft x 24 ft Boom at B/W = 33.6 at 0.490 fps - Run 110
0.75 ft Significant Height Irregular Waves

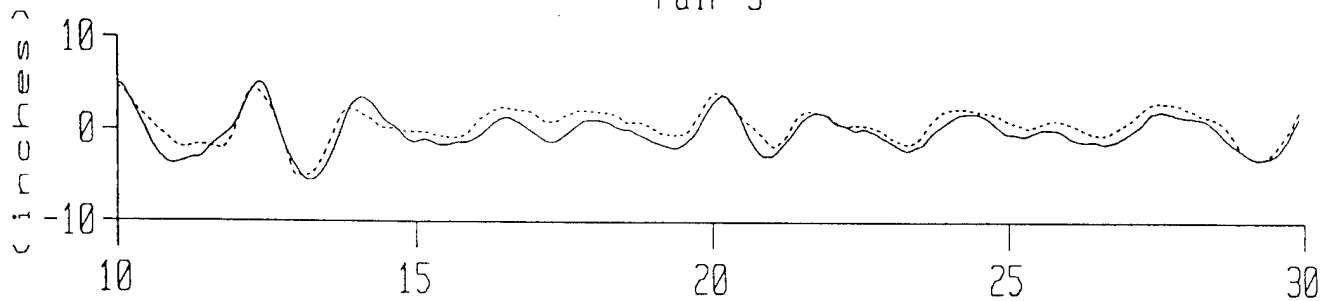
Pair 0



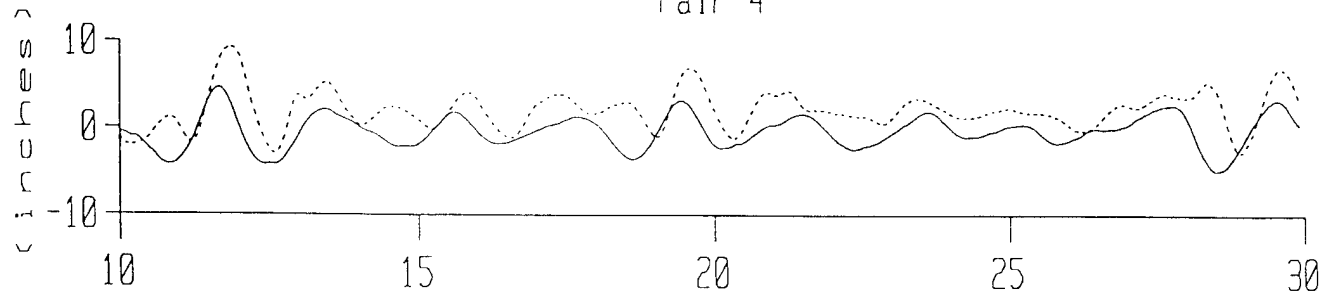
Pair 2



Pair 3



Pair 4



Time (sec)

FIGURE 15 COMPARISONS OF HEAVE AND WAVE MODEL MEASUREMENTS

1.5 ft x 24 ft Boom at B/W = 10.3 at 0.503 fps - Run 126
0.75 ft Significant Height Irregular Waves

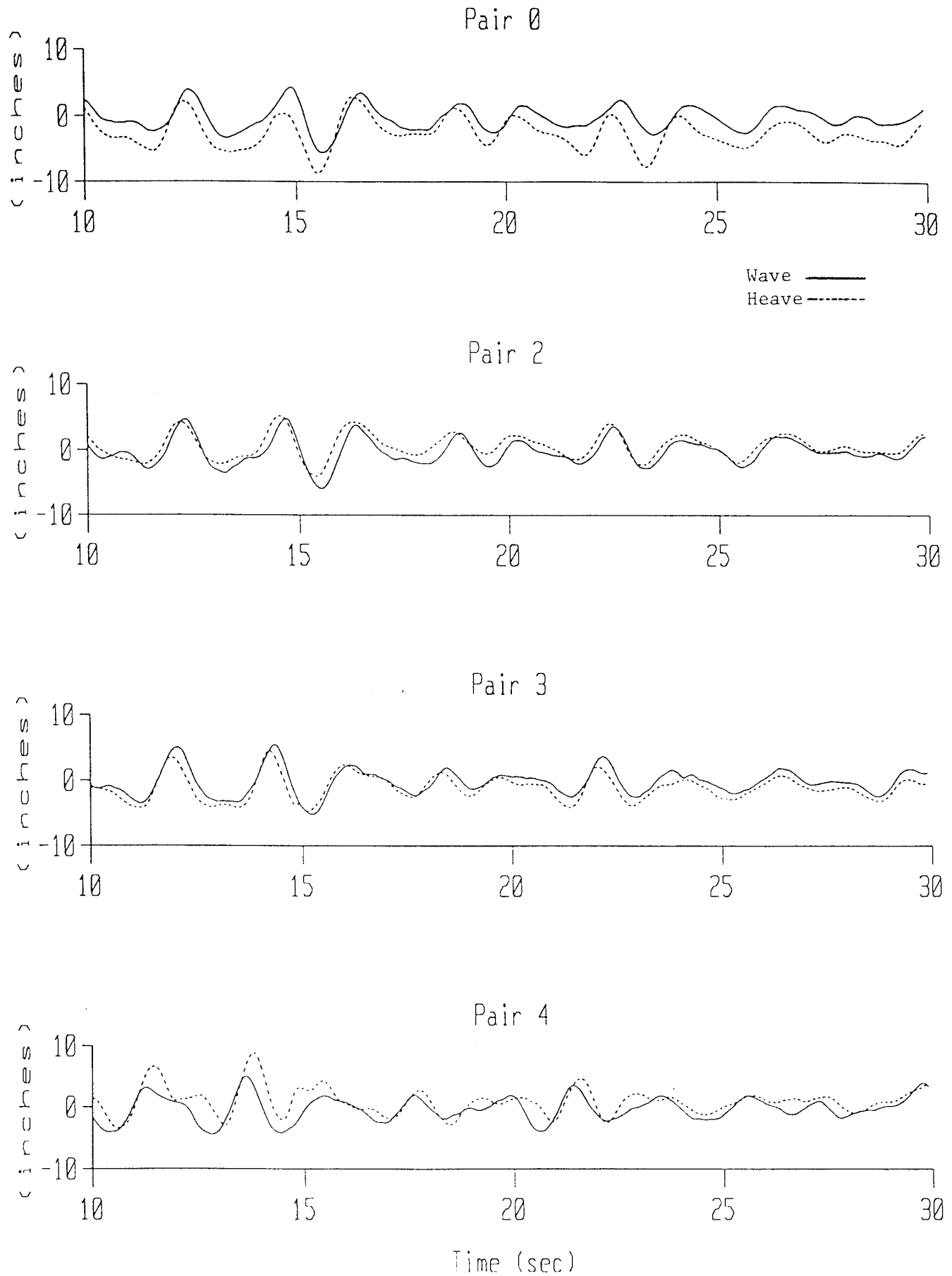


FIGURE 16 COMPARISONS OF HEAVE AND WAVE MODEL MEASUREMENTS

1.5 ft x 24 ft Boom at B/W = 5.0 at 0.501 fps - Run 142
0.75 ft Significant Height Irregular Waves

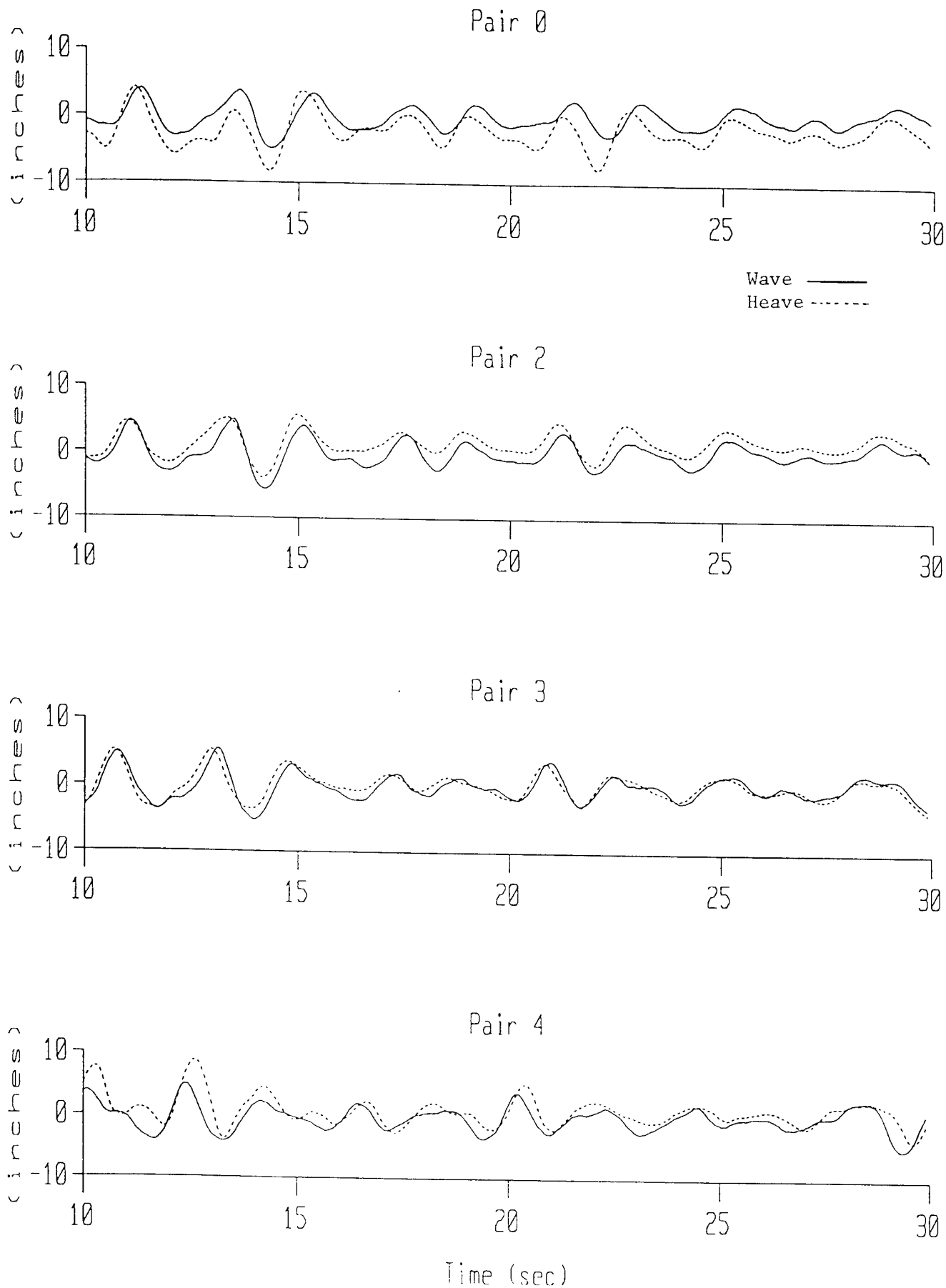


FIGURE 17 COMPARISONS OF HEAVE AND WAVE MODEL MEASUREMENTS

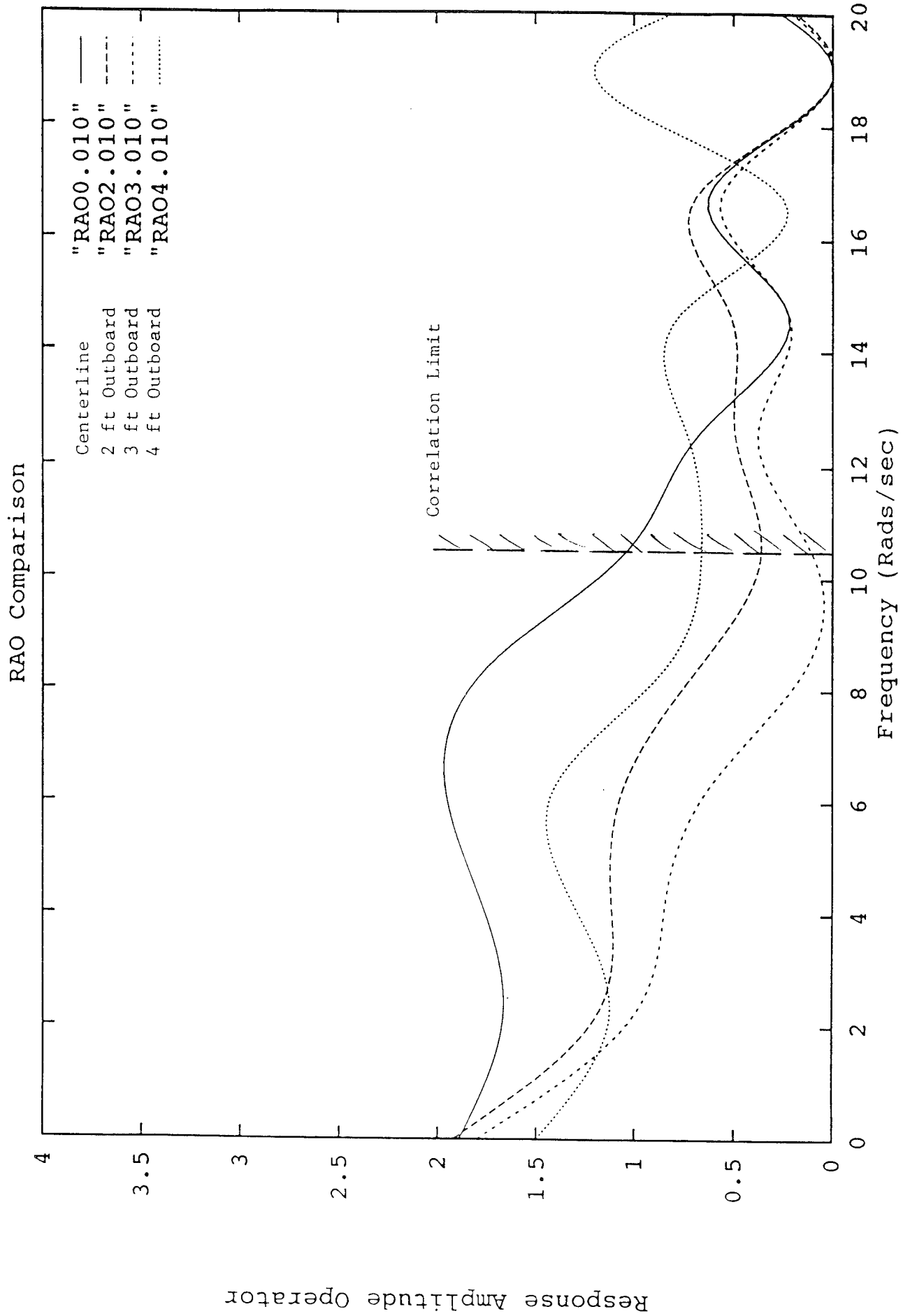


FIGURE 18 MODEL SCALE HEAVE RAO vs ENCOUNTER FREQUENCY AT $B/W = 34.3$
 1 ft x 24 ft Boom in 0.5 ft Irregular Waves at 0.416 fps - Run 10

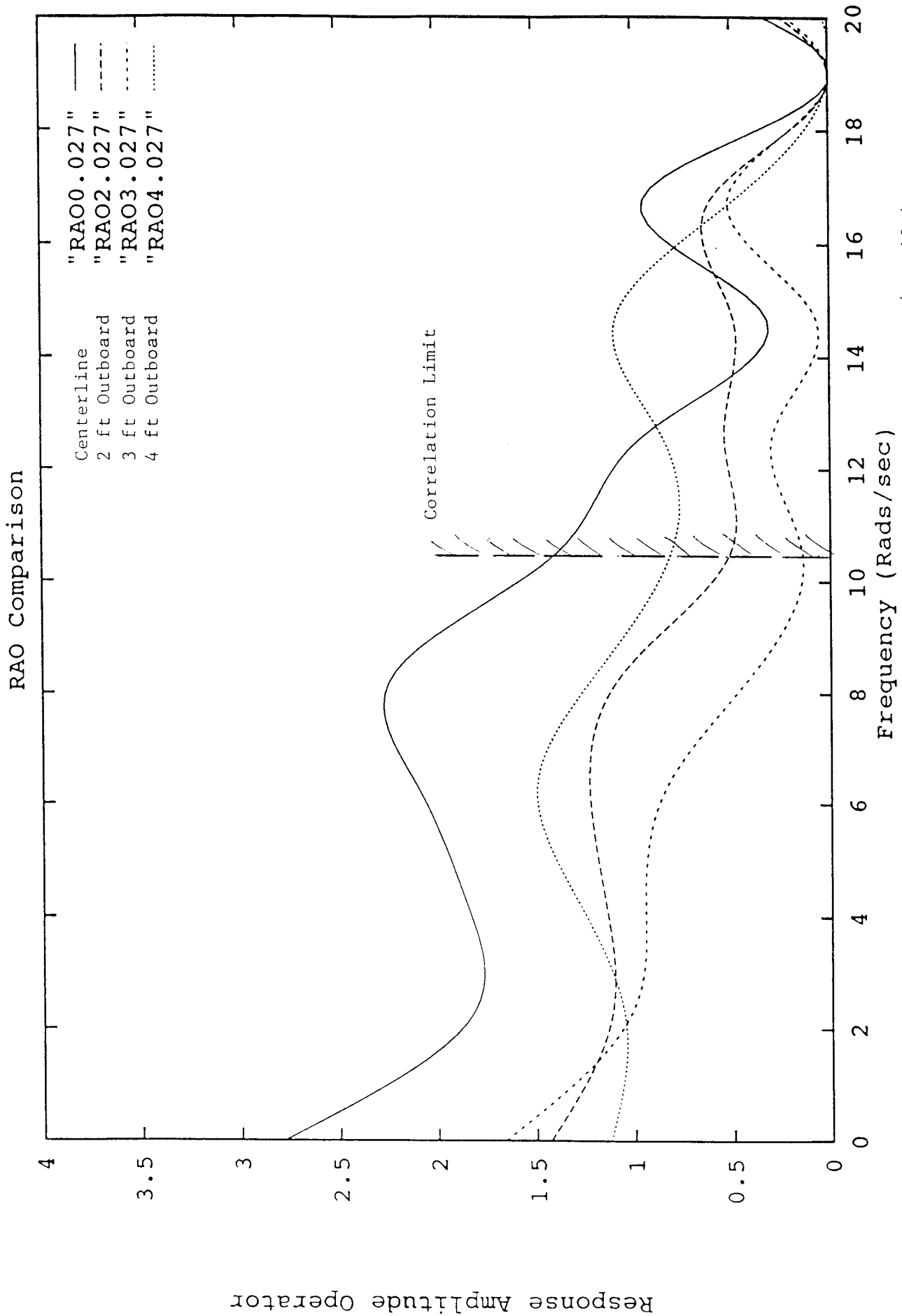


FIGURE 19 MODEL SCALE HEAVE RAO vs ENCOUNTER FREQUENCY AT $B/W = 10.4$
 1 ft x 24 ft Boom in 0.5 ft Irregular Waves at 0.425 fps - Run 27

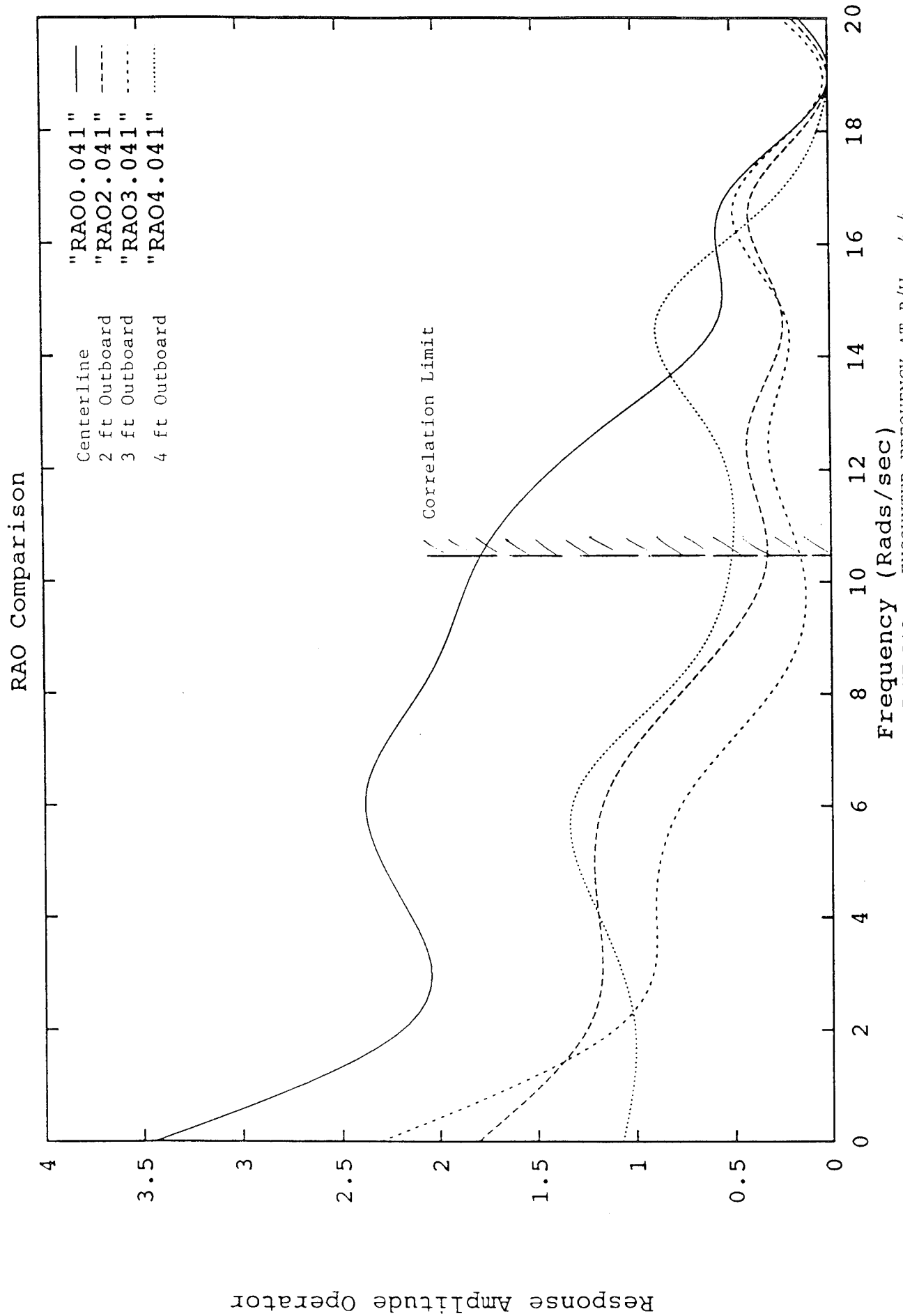


FIGURE 20 MODEL SCALE HEAVE RAO vs ENCOUNTER FREQUENCY AT $B/W = 4.4$
 1 ft x 24 ft Boom in 0.5 ft Irregular Waves at 0.436 fps - Run 41

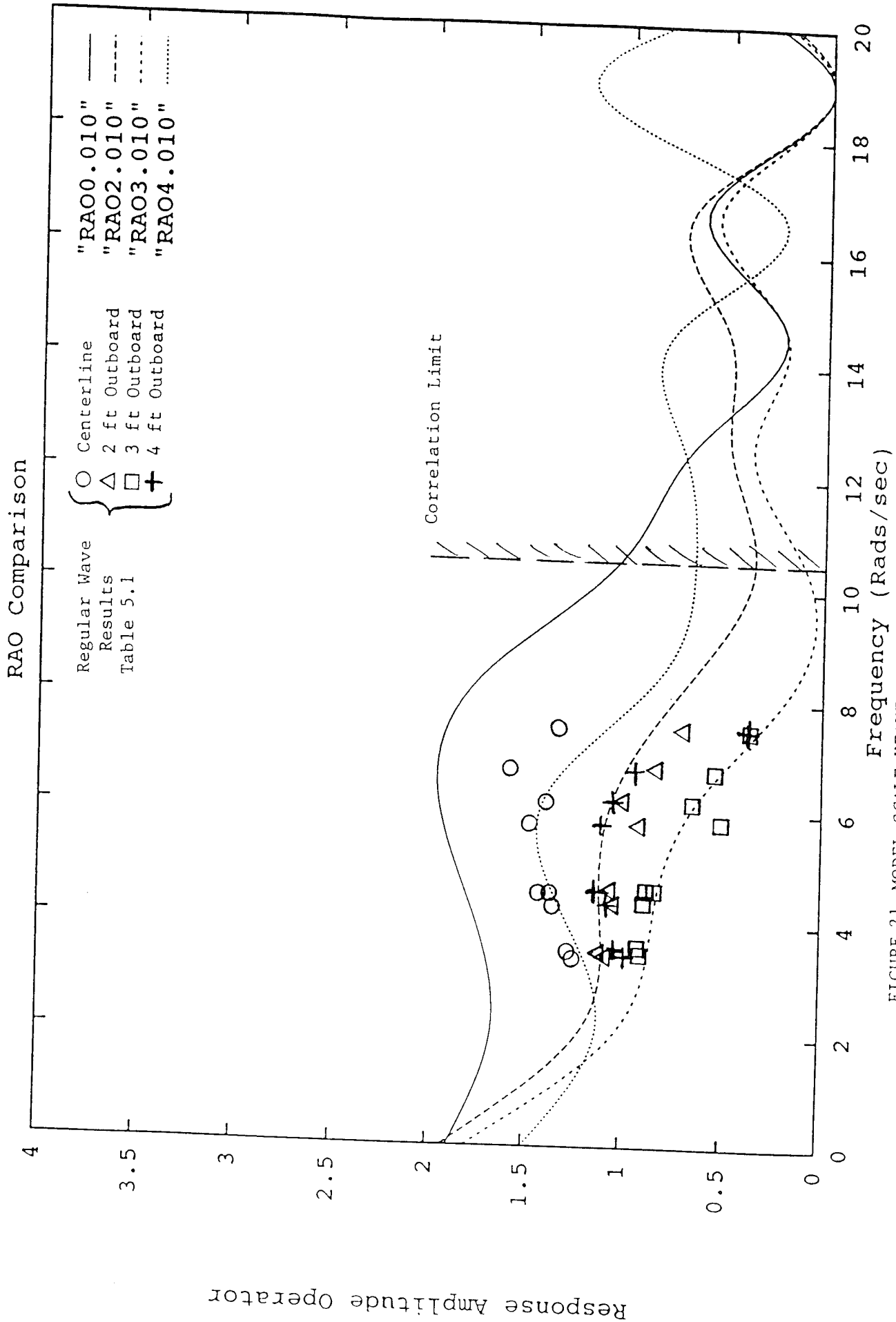


FIGURE 21 MODEL SCALE HEAVE RAO vs ENCOUNTER FREQUENCY AT $B/W = 34.3$
 1 ft x 24 ft Boom in 0.5 ft Irregular Waves at 0.416 fps - Run 10

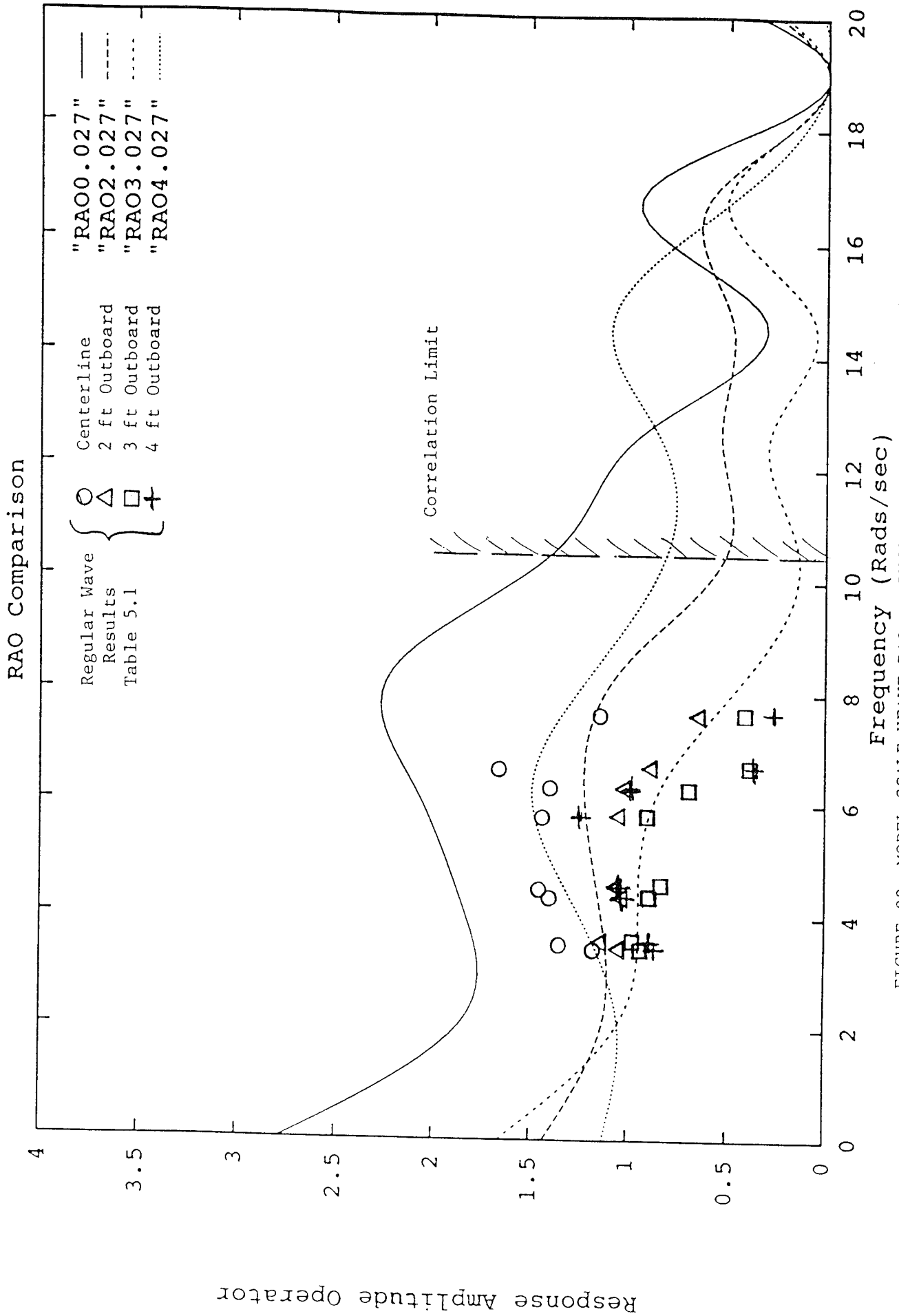


FIGURE 22 MODEL SCALE HEAVE RAO vs ENCOUNTER FREQUENCY AT $B/W = 10.4$
1 ft x 24 ft Boom in 0.5 ft Irregular Waves at 0.425 fps - Run 27

RAO Comparison

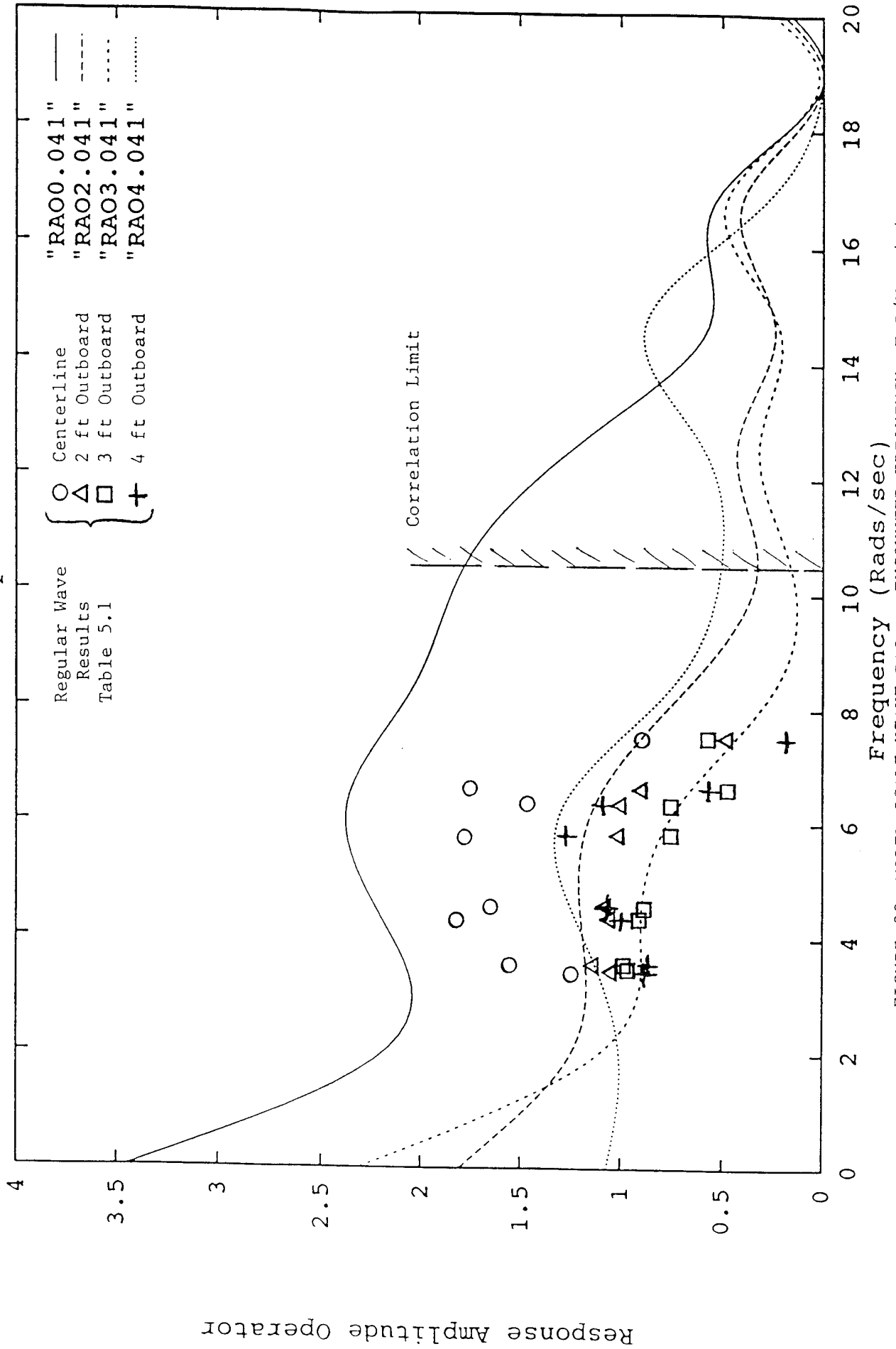


FIGURE 23 MODEL SCALE HEAVE RAO vs ENCOUNTER FREQUENCY AT $B/W = 4.4$
1 ft x 24 ft Boom in 0.5 ft Irregular Waves at 0.436 fps - Run 41

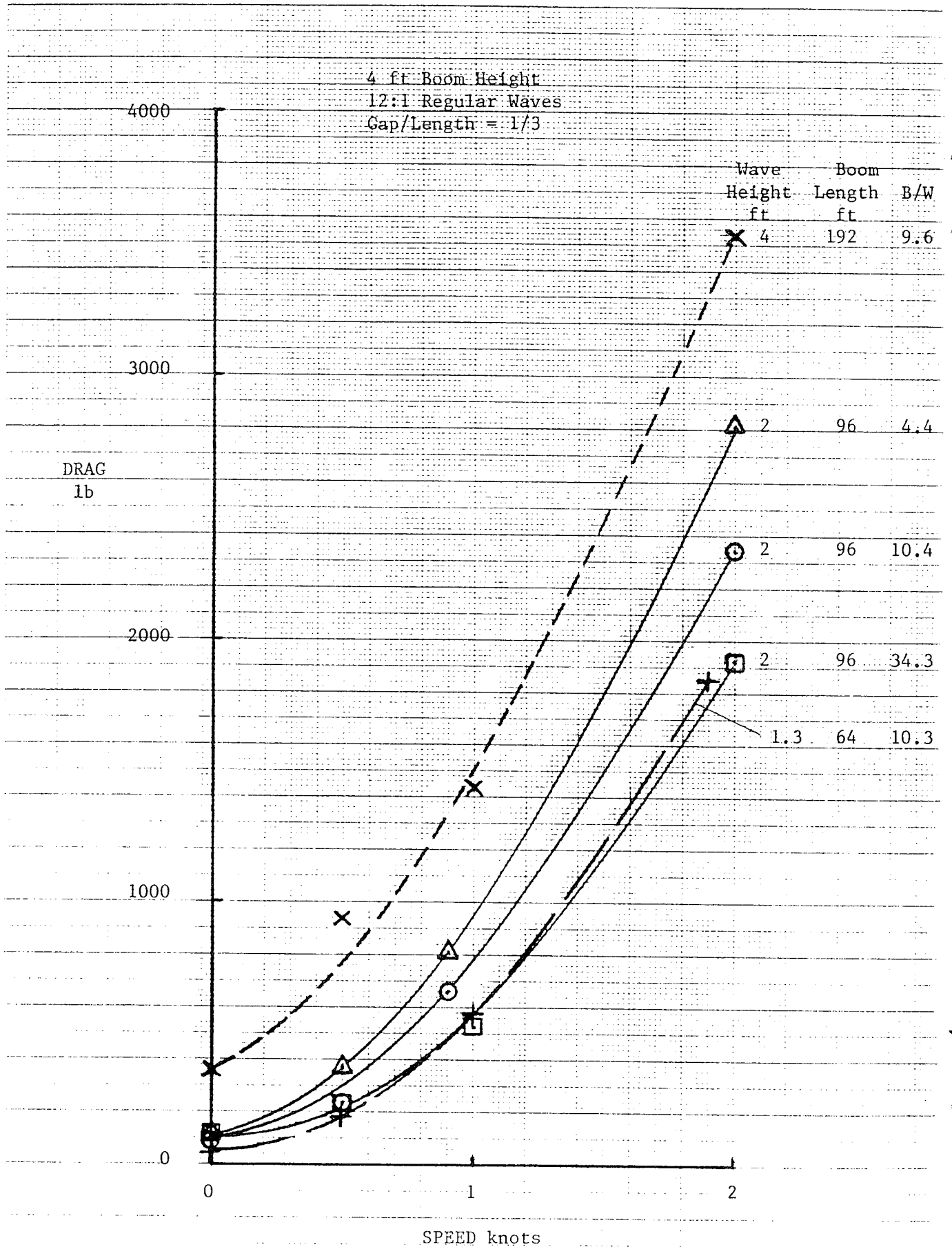


FIGURE 24 DRAG vs. SPEED

Room Wave Calibrations

Scalar Spectrum Analysis

Page 1 of 1 Channel 1
Wave in

Run= 10,

645 Points 30 Lags Delta-T= 0.200000 Sec
 Scale constant= 1.000000E+00 Delta-Freq.= 0.083 Hertz

Sample Variance= 2.295474E+00 *90% Conf Intv.= 2.099385E+00 (Low)
 Spectrum Area = 2.295474E+00 * = 2.522144E+00 (High)

43 Deg. Freedom: for 90% Conf. Bounds Multiply
 Spectral Estimates by 0.73 and 1.48
 Sig Wave Height = 6.0603 Inches

m0= 2.295 m1= 1.459
 m2= 1.046 m3= 0.8705 m4= 0.8671
 Modal period = 2.022 Sec (0.495 Hz)
 Average period (m0/m1) = 1.573 Sec (0.636 Hz)
 Z-cross period (sqrt(m0/m2)) = 1.481 Sec (0.675 Hz)
 Band-width Parameter (sqrt(1-m2**2/(m0*m4))) = 0.671

Lag	Frequency	Spectral Estimates*	ITTC Spectrum +
0	0.000	8.4037E-03	0.0000E+00 *
1	0.083	2.4749E-02	5.3743E-12 *
2	0.167	6.8869E-04	1.6795E-13 *
3	0.250	7.5647E-02	3.4111E-06 *
4	0.333	1.0181E+00	3.9110E-01 + *
5	0.417	3.6693E+00	4.5818E+00 + *
6	0.500	5.6559E+00	6.6537E+00 + *
7	0.583	5.6228E+00	5.3395E+00 + *
8	0.667	4.1702E+00	3.5779E+00 + *
9	0.750	2.6712E+00	2.2890E+00 + *
10	0.833	1.6696E+00	1.4661E+00 + *
11	0.917	8.4631E-01	9.5619E-01 + *
12	1.000	6.1310E-01	6.3844E-01 + *
13	1.083	4.8123E-01	4.3673E-01 + *
14	1.167	2.7757E-01	3.0573E-01 + *
15	1.250	1.5954E-01	2.1865E-01 *
16	1.333	1.6952E-01	1.5945E-01 *
17	1.417	1.5057E-01	1.1836E-01 *
18	1.500	8.3482E-02	8.9275E-02 *
19	1.583	3.3314E-02	6.8324E-02 *
20	1.667	2.8896E-02	5.2985E-02 *
21	1.750	2.3912E-02	4.1586E-02 *
22	1.833	2.4143E-02	3.3000E-02 *
23	1.917	1.4542E-02	2.6452E-02 *
24	2.000	1.4649E-02	2.1400E-02 *
25	2.083	8.7755E-03	1.7462E-02 *
26	2.167	1.1329E-02	1.4360E-02 *
27	2.250	7.1525E-03	1.1897E-02 *
28	2.333	8.5863E-03	9.9225E-03 *
29	2.417	3.8212E-03	8.3285E-03 *
30	2.500	6.0244E-03	7.0319E-03 *

APPENDIX A-1
 IRREGULAR WAVE SPECTRUM
 6 INCH SIGNIFICANT HEIGHT

Room Wave Calibrations

Scalar Spectrum Analysis

Page 1 of 1 Channel 1
Wave in

Run= 9,

645 Points 30 Lags Delta-T= 0.200000 Sec
 Scale constant= 1.000000E+00 Delta-Freq.= 0.083 Hertz

Sample Variance= 5.038975E+00 *90% Conf Intv.= 4.608525E+00 (Low)
 Spectrum Area = 5.038975E+00 * = 5.536557E+00 (High)

43 Deg. Freedom: for 90% Conf. Bounds Multiply
 Spectral Estimates by 0.73 and 1.48
 Sig Wave Height = 8.9791 Inches

m0= 5.039 m1= 2.616
 m2= 1.543 m3= 1.061 m4= 0.8831
 Modal period = 2.484 Sec (0.403 Hz)
 Average period (m0/m1) = 1.926 Sec (0.519 Hz)
 Z-cross period (sqrt(m0/m2)) = 1.807 Sec (0.553 Hz)
 Band-width Parameter (sqrt(1-m2**2/(m0*m4))) = 0.682

Lag	Fre- quency	Spectral Estimates*	ITTC Spectrum +	
0	0.000	1.7319E-01	0.0000E+00	*
1	0.083	9.0253E-02	5.1696E-12	*
2	0.167	1.3767E-01	1.6155E-13	*
3	0.250	1.8877E+00	1.5258E-01	+ *
4	0.333	8.9676E+00	1.1278E+01	!
5	0.417	1.5310E+01	1.7745E+01	!
6	0.500	1.3130E+01	1.2529E+01	!
7	0.583	8.3969E+00	7.3808E+00	!
8	0.667	4.8514E+00	4.2566E+00	!
9	0.750	2.8558E+00	2.5142E+00	!
10	0.833	1.8020E+00	1.5385E+00	!
11	0.917	1.1053E+00	9.7613E-01	!
12	1.000	6.4884E-01	6.4046E-01	!*
13	1.083	4.3315E-01	4.3310E-01	!*
14	1.167	2.6909E-01	3.0083E-01	!*
15	1.250	1.4105E-01	2.1397E-01	*
16	1.333	8.3871E-02	1.5543E-01	*
17	1.417	6.5825E-02	1.1504E-01	*
18	1.500	5.1234E-02	8.6591E-02	*
19	1.583	4.4385E-02	6.6163E-02	*
20	1.667	2.9273E-02	5.1245E-02	*
21	1.750	2.0588E-02	4.0182E-02	*
22	1.833	1.4594E-02	3.1862E-02	*
23	1.917	1.0427E-02	2.5524E-02	*
24	2.000	6.0393E-03	2.0640E-02	*
25	2.083	6.5076E-03	1.6834E-02	*
26	2.167	5.0304E-03	1.3840E-02	*
27	2.250	6.9904E-03	1.1462E-02	*
28	2.333	4.5282E-03	9.5583E-03	*
29	2.417	4.1125E-03	8.0212E-03	*
30	2.500	2.4698E-03	6.7714E-03	*

APPENDIX A-2
 IRREGULAR WAVE SPECTRUM
 9 INCH SIGNIFICANT HEIGHT

Boom Conformance Tests

Scalar Spectrum Analysis

Page 1 of 1 Channel 8
Wave 4, in

Run= 60,

924 Points 30 Lags Delta-T= 0.250000 Sec
 Scale constant= 1.000000E+00 Delta-Freq.= 0.067 Hertz

Sample Variance= 9.821496E+00 *90% Conf Intv.= 9.112664E+00 (Low)
 Spectrum Area = 9.821497E+00 * = 1.062153E+01 (High)

61 Deg. Freedom: for 90% Conf. Bounds Multiply
 Spectral Estimates by 0.76 and 1.39
 Sig Wave Height = 12.5357 Inches

m0= 9.821 m1= 4.561
 m2= 2.468 m3= 1.601 m4= 1.277
 Modal period = 2.773 Sec (0.361 Hz)
 Average period (m0/m1) = 2.154 Sec (0.464 Hz)
 Z-cross period (sqrt(m0/m2)) = 1.995 Sec (0.501 Hz)
 Band-width Parameter (sqrt(1-m2**2/(m0*m4))) = 0.717

Lag	Fre- quency	Spectral Estimates*	ITTC Spectrum +	
0	0.000	6.2897E-01	0.0000E+00	+
1	0.067	5.9232E-01	1.9822E-11	+
2	0.133	4.6584E-01	6.1945E-13	*
3	0.200	2.3772E+00	4.7533E-03	+
4	0.267	1.3417E+01	9.4316E+00	+
5	0.333	2.8128E+01	3.6466E+01	+
6	0.400	3.3248E+01	3.5561E+01	*
7	0.467	2.6107E+01	2.4059E+01	+
8	0.533	1.3990E+01	1.4840E+01	*
9	0.600	7.6527E+00	9.0844E+00	+
10	0.667	5.9505E+00	5.6737E+00	*
11	0.733	4.7877E+00	3.6445E+00	+
12	0.800	3.1028E+00	2.4100E+00	+
13	0.867	2.0875E+00	1.6382E+00	+
14	0.933	1.8103E+00	1.1418E+00	+
15	1.000	1.0590E+00	8.1416E-01	*
16	1.067	5.9690E-01	5.9245E-01	*
17	1.133	4.2700E-01	4.3907E-01	*
18	1.200	3.3571E-01	3.3079E-01	*
19	1.267	2.0751E-01	2.5294E-01	*
20	1.333	1.4146E-01	1.9602E-01	*
21	1.400	9.6933E-02	1.5377E-01	*
22	1.467	7.9066E-02	1.2197E-01	*
23	1.533	5.9088E-02	9.7734E-02	*
24	1.600	6.4571E-02	7.9047E-02	*
25	1.667	5.2767E-02	6.4484E-02	*
26	1.733	3.8608E-02	5.3023E-02	*
27	1.800	3.1662E-02	4.3919E-02	*
28	1.867	4.5112E-02	3.6627E-02	*
29	1.933	3.5424E-02	3.0740E-02	*
30	2.000	3.8797E-02	2.5952E-02	*

APPENDIX A-3
 IRREGULAR WAVE SPECTRUM
 12 INCH SIGNIFICANT HEIGHT

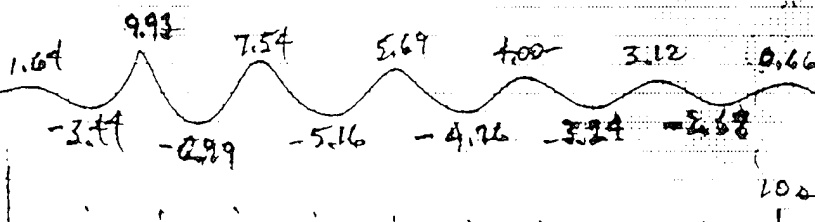
HEAVE

Run : 15 7 Oscillations
Ch 1 : Wave in Buffer : 0.500

Peaks	Troughs
1.636	-3.437
9.932	-6.990
7.536	-5.156
5.685	-4.264
3.999	-3.239
3.123	-2.677
0.661	-0.066

pktn R P C C I K L H O O . ?? c 15
Which channel ? 1

MT-8600 MULTI-TASK RECORDER



WAVE WIRE

CARR TACH

APPENDIX A-4
BREAKING WAVE TIME HISTORY SAMPLE